SCIENCE-IX

MODULE - 8

INDEX

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WORK & ENERGY

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WORK & ENERGY

WORK

The intuitive meaning of work is quite different from the scientific definition of work. In everyday activity, the term 'work' is used equally for mental work and for physical work (involving muscular force) as is clear from the following examples.

(i) You may read a book or exert yourself mentally in thinking about a simple or difficult problem.

(ii) You might be holding a weight without moving.

(iii) You may be carrying a load and moving with uniform velocity.

(iv) You may be trying hard to move a huge rock which does not move despite your best efforts, though you may get completely exhausted in the process.

In all these cases, according to scientific definition, you are not doing any work.

SCIENTIFIC CONCEPTION OF WORK

In physics, the term work is used in a special technical sense and has a much more precise definition which follows from the following examples.

(i) When a box is pushed on a floor by applying a force and it moves through some distance, work is said to be done. In this case, the applied force displaces the box.

(ii) When we pull a trolley by applying a force and it moves through some distance, work is again said to be done.

(iii) When we lift a box through a height, we have to apply force. In this case, the applied force does work in lifting the box.

From all the examples given above, it follows that work is done if :

(a) a force is applied on the object and

(b) the object is displaced from its original position.

No work is said to be done if any of the two conditions is not satisfied.

UNITS OF WORK DONE

Work done, $W = Fd$

In C.G.S. system the unit of work done is **dyne x cm = erg.**

Definition of 1 erg:

If $F = 1$ dyne and $d = 1$ cm

then, $W = 1 \times 1 = 1$ erg.

If one dyne force is applied on a body and displacement in the body is 1 cm in the direction of force, then work done will be one erg.

S.I. unit of work done is **newton × metre = joule**

Definition of 1 joule:

If $F = 1N$ and $d = 1m$

then, $W = 1 \times 1 = 1$ joule (J)

If a force 1 Newton is applied on a body and displacement in the body is 1m in the direction of force then work done will be 1 joule.

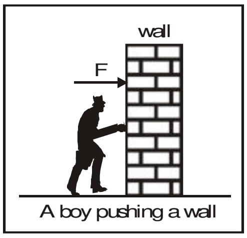
Relation between joule and erg:

1 joule = 10^7 erg

Erg and joule are the absolute units of work done.

CONCLUSION

1. When $s = 0$, $W = 0$, i.e. work done by a force on a body is zero if the displacement of the body is zero. For example, when you push a wall with a force F, then the displacement of the wall is zero. Therefore, the work done by force F on the wall is zero.

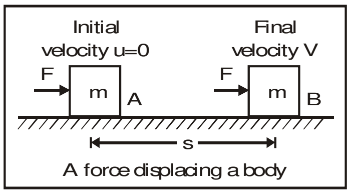


A boy pushing a wall

2. When you sit on a chair and prepare a lesson in two hours, you may feel tired. But according to physics, no work is done.
3. If you hold a briefcase for one hour and do not move the briefcase, then $s = 0$. Therefore, work done by you on the briefcase is zero.

WORK: WHEN CONSTANT FORCE IS ACTING IN THE DIRECTION OF DISPLACEMENT

A body A is kept on a smooth horizontal surface. A force F is applied as shown. This force acts on the body for some time during which the displacement of the body is s. In such a case work is defined as follows.



A force displacing a body

Work done by a force on a body is the product of force and displacement of the body in the direction of the force.

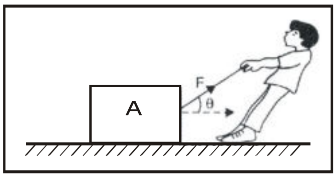
Work = Force × Displacement

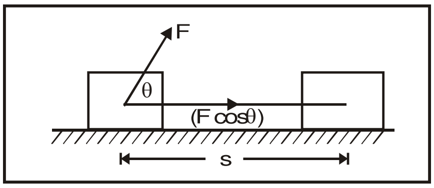
$\Rightarrow$ $W = F \times s$

Work is a scalar quantity. This means that it has no sense of direction.

WORK: WHEN A CONSTANT FORCE IS ACTING AT AN ANGLE TO THE DISPLACEMENT

Let us consider a body A lying on a smooth horizontal surface. A constant force F acts at an angle θ to the horizontal. The body is displaced through a distance s in the horizontal direction. Here the complete force F is not responsible to displace the body. A part of the force acting in the direction of displacement is responsible for displacing the body. This horizontal part is $F \cos \theta$. Work done in this case is defined as 'work done by a constant force acting at an angle to the displacement is the product of component of force in the direction of displacement and the displacement of the body'.





Work = Component of force in the direction of displacement x Displacement

$W = (F \cos \theta) \times s$

$W = F s \cos \theta$

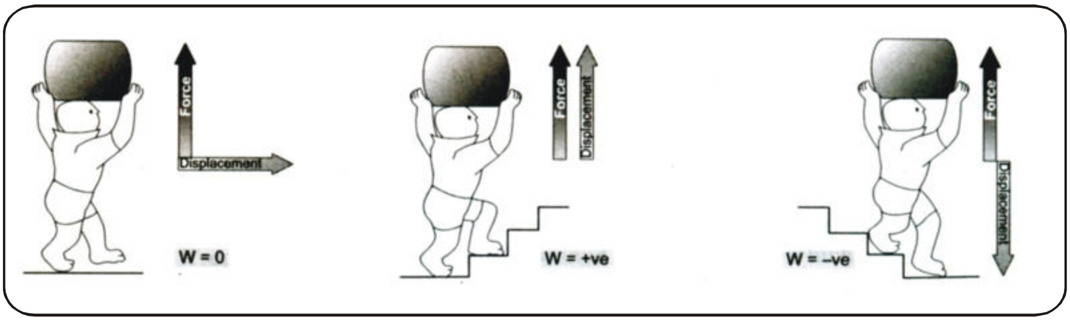
WORK DONE IS MAXIMUM WHEN FORCE ACTS IN THE DIRECTION OF DISPLACEMENT.

CASE-1 : Work done is positive when θ is acute. This is because $\cos \theta$ is positive, Work done is maximum when $\theta = 0°$. This is because the maximum value of $\cos \theta = 1$. This happens when force acts in the direction of displacement.

CASE-2 : When the angle between force and displacement is 90°, i.e. when $\theta = 90°$, then

$\cos \theta = 0 \qquad \cos 90° = 0$

$W = 0$



Some examples where work done is zero because $\theta = 90°$

(a) WORK DONE BY CENTRIPETAL FORCE: When a stone is whirled in a horizontal circle, then centripetal force acts at 90° to the displacement. Therefore, work done by centripetal force is zero.

(b) WORK DONE BY COOLIE: When a coolie moves on a horizontal surface, he applies a force on the load kept on his head in vertically upward direction. Therefore, $\theta = 90°$. Therefore, work done by the force applied by coolie is zero.

(c) MOTION OF THE EARTH AROUND THE SUN: Work done by the centripetal force (which is the gravitational pull of sun on earth) acting on earth is zero. Because centripetal force is perpendicular to the displacement.

[Remember the displacement is always tangential and centripetal force is always radically inward. The angle between radius and tangent is 90°].

CASE-3 : When angle between force and displacement is 180°, i.e. when $\theta = 180°$ then $\cos 180° = -1$.

In this case work done is negative.

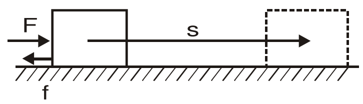
Let us take an example where work done is negative because $\theta = 180°$

A block A is pushed by the force F and displaced through s. Work done by applied force,

$$W = F \times s \times \cos 0°$$
$$= Fs$$

Work done by frictional force,

$$W = f \times s \times \cos 180°$$
$$= -fs$$



Work done by friction is negative.

NOTE : WORK MAY BE POSITIVE, NEGATIVE OR ZERO DEPENDING ON THE ANGLE θ.

Newton's Thought

An artificial satellite is moving around the Earth in a circular path under the influence of centripetal force provided by the gravitational force between them. What is the work done by this centripetal force?

Explanation

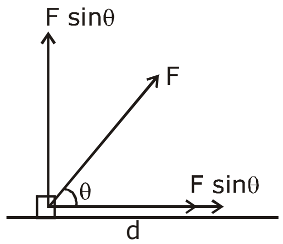
Centripetal force (F) is always perpendicular to the displacement (s) of the particle moving along a circular path. That is, the angle (θ) between them is 90°.

Now, work done, $Fs \cos\theta = Fs \cos 90° = 0$ [$\because \cos 90° = 0$]

Thus, work done this centripetal force is zero.

◈ **Positive Work done:**

When the angle between force and the displacement is acute ($\theta < 90°$), then work done will be positive because one component of force ($F\cos\theta$) is in the direction of displacement so work done by this component will be positive ($Fd\cos\theta$). Work done by the vertical component (i.e $F\sin\theta$) will be zero ($\because$ the angle between $F\sin\theta$ and displacement is $90°$) so net work done will be positive.

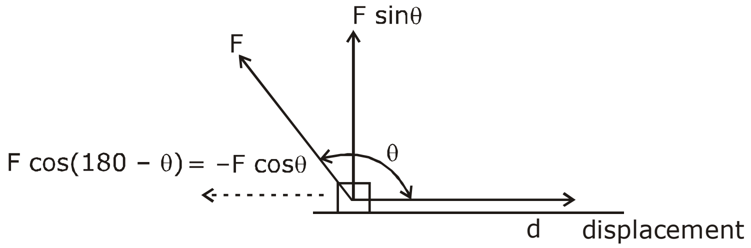


(i) In lifting weight upward by applying an upward force the work done by the applied force will be positive.

(ii) In stretching a spring, the work done by the external force will be positive.

◈ **Negative Work done:**

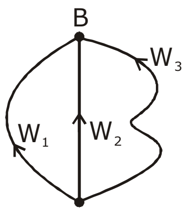
When the angle between the force and the displacement is obtuse, ($\theta > 90°$), then work done will be negative because work done by the horizontal component of force (i.e. $F\cos\theta$) is negative ($-Fd\cos\theta$) and the work done by the vertical component ($F\sin\theta$) will be zero, so net work done will be negative.



CONSERVATIVE FORCES

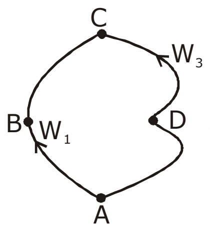
Conservative forces are defined by following three ways.

(i) Work done by a conservative force in moving a body from one position to another depends only on the initial and final positions and not on the length of the path followed between to positions.



$W_1 = W_2 = W_3$

(ii) Work done by conservative force in moving a complete round is always Zero.



$W_{ABCDA} = 0$

(iii) Energy of the body after one complete round remain unchanged, then the force by which this work is held will be a conservative force.

Examples of Conservative forces:

Gravitational force, Restoring force, Electrical force, Lorenz force etc.

NON CONSERVATIVE FORCES

If work done by the force depends on the path then force is called non conservative force.

E.g.: Frictional force, Viscous force, etc.

ENERGY

When a car runs, the engine of the car generates a force which displaces the car. In other words, work is done by the car. This work is done on the expense of fuel. Fuel provides the energy needed to run the car. Had the petrol tank been empty, car could not be run. The conclusion is that, if there is no source of energy, no work will be done.

Let us take another example. Suppose a lift takes some persons from ground floor to second floor. Then the lift performs work. If you enquire, you will find that the lift is operated by an electrical motor. Thus, electrical energy does the work. If there is no electricity the lift will not operate. Again if there is no source of energy, no work will be done.

The above statement is not just true for the above two examples, but is true for all processes.

Therefore, energy is defined as the capacity to do work. Energy is the ability to do work. More the energy, more the work that can be performed and vice-versa.

UNITS OF ENERGY

Energy is a scalar quantity.

The S.I. unit of energy is joule (J). (Bigger units is 1 kJ = 1000 J, 1 MJ = 10^6 J)

The C.G.S. unit of energy is erg.

◈ **NOTE:**

(i) kilo Watt × hour (kWh) is commercial unit of energy.

$$1 \text{ kWh} = 1000 \text{ watt} \times 60 \times 60 \text{ sec}$$

$$= 3.6 \times 10^6 \text{ watt} \times \text{sec.}$$

$$1 \text{ kWh} = 3.6 \times 10^6 \text{ J.}$$

(ii) Electron volt (eV) is also the unit of energy. The energy of an electron, when it is accelerated by a potential difference of 1 volt, is known as one eV

$$1\text{eV} = 1.6 \times 10^{-19}\text{J}$$

FORMS OF ENERGY

Nature-has been very kind to us in providing us energy in various forms. These forms of energy are as follows.

1. **SOLAR ENERGY.** The energy radiated by the Sun is called solar energy. Plants collect and store this energy to make food through photosynthesis.
2. **HEAT ENERGY.** It is the energy released when coal, oil, gas or wood burn and it produces in us the sensation of warmth.
3. **LIGHT ENERGY.** It is the form of energy which produces in us the sensation of light. Sun is the natural source of light.
4. **CHEMICAL ENERGY.** It is the energy possessed by fossil fuels (coal; petroleum and natural gas) and is also called the fuel energy. The food that we eat has chemical energy stored in it.

5. **HYDRO ENERGY.** The energy possessed by water flowing in rivers and streams is called hydro energy. This energy is used to generate electricity in hydroelectric power plants.

6. **WIND ENERGY.** The energy possessed by moving air is called wind energy.

7. **OCEAN THERMAL ENERGY (OTE).** Solar energy stored in the oceans in the form of heat is called ocean thermal energy.

8. **GEOTHERMAL ENERGY.** It is the heat energy of the Earth and is found within rock formations and the fluids held within those formations.

9. **BIOMASS ENERGY.** It is the energy obtained from biomass (i.e., living matter or its residues).

10. **TIDAL ENERGY.** It is the energy derived from the rising and falling ocean tides.

11. **SOUND ENERGY.** It is the energy possessed by vibrating objects and it produces in us the sensation of hearing.

12. **MECHANICAL ENERGY.** It is the energy possessed by a body due to its position (or configuration) or motion. The energy possessed due to position or configuration is called potential energy and that due to motion is called kinetic energy. The sum of these two energies is called the mechanical energy.

13. **ELECTRIC ENERGY.** The energy possessed by charges (either at rest or in motion) is called electric energy.

14. **MAGNETIC ENERGY.** It is the energy possessed by magnetised bodies e.g. a magnet.

15. **ELECTROMAGNETIC ENERGY.** It is the general name for electric and magnetic energies.

16. **NUCLEAR ENERGY.** The energy produced in the processes of fission and fusion is called nuclear energy.

KINETIC ENERGY

A moving object is capable of doing work because of it" motion. Hence, we say that the object has kinetic energy. **"Kinetikos"** in Greek means **"to move"**. Hence, **kinetic energy means energy due to motion**. The energy is stored in the object when work is done to change its velocity from a lower value to a higher value, or from rest to certain velocity.

Kinetic energy of an object is defined as the energy which it possesses by virtue of its motion, and is measured by the amount of work that the object can do against an opposing force before it comes to rest.

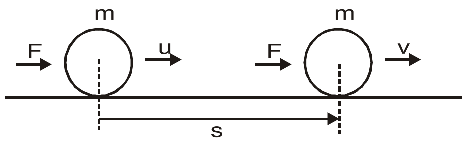
Kinetic energy of an object moving with a certain velocity is equal to the work done on it to enable it to acquire that velocity.

EXAMPLES OF BODIES POSSESSING KINETIC ENERGY

1. A ball rolling on a surface because it can set another ball into motion by striking it.
2. A bullet fired from a gun as it is able to penetrate some distance into a target which it strikes.
3. A tarpedo in motion as it can do work by penetrating into the side' of a ship.
4. Water in motion as it can turn a wheel or a turbine.
5. A fast wind as it can set a boat in motion when striking against its sail.
6. A moving hammer as it drives a nail into a wall against the resistance offered to it by the wall.
7. A falling body as it can break something on which it falls.

EXPRESSION FOR KINETIC ENERGY

Consider an object of mass m which is moving with an initial velocity u on a perfectly frictionless surface. Let a constant external force F act on it and produce an acceleration a in it. If v is the final velocity of the object after having undergone a displacement s, then from



$v^2 - u^2 = 2as, s = \frac{v^2 - u^2}{2a}$ ...(1)

Work done by the force in displacing the body through s, i.e.,

$W = F \times s$ ...(2)

We know from **Newton's Second Law of Motion**,

$F = ma$ ...(3)

From equation (1), (2) and (3), we get

$W = (ma) \times \frac{(v^2 - u^2)}{2a} = \frac{m(v^2 - u^2)}{2}$

or $W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$ ... (4)

If the object is initially at rest, u = 0 and as such from eqn. (4),

$W = \frac{1}{2}mv^2$ ...(5)

This work done (W) in making the object acquire a velocity v after starting from rest has not gone waste and is, in fact, stored in the object.

Work stored up in a moving object is called the kinetic energy of the object.

If kinetic energy of an object is denoted by E_k then

$E_k = \frac{1}{2}mv^2$ ...(6)

Kinetic energy of a moving object is defined as half the product of the mass of the object and the square of the speed of the object.

❖ **Factors affecting Kinetic energy:**

(i) The more the mass of a body, the greater its kinetic energy.

(ii) The more the velocity of a body, the more its kinetic energy.

(iii) Kinetic energy of a body depends both on its mass and velocity.

RELATION BETWEEN WORK DONE AND KINETIC ENERGY

Work Energy Theorem: This theorem states that the work done by the forces acting on a body is equal to the change in the kinetic energy of the body.

Consider a body of mass m moving with a velocity u. Let a force F be applied on the body, so that it is accelerated with an acceleration 'a'.

Then, F = ma

If a be the distance travelled by the body during its accelerated motion, then the work done by the force F is given by W = Fs = mas,

Since (F = ma) ...(i)

Let the body acquires velocity v after travelling a distance s, the from $v^2 - u^2 = 2as$, we have

$$a = \frac{v^2 - u^2}{2s} \qquad \text{...(ii)}$$

Put this value in equation (equation-i), we get

$$W = m\left(\frac{v^2 - u^2}{2s}\right) \times s = \frac{1}{2}mv^2 - \frac{1}{2}mu^2 \qquad \text{...(iii)}$$

Here $\frac{1}{2}mv^2$ = Final K.E. and $\frac{1}{2}mu^2$ = Initial K.E.

Now as W = Fs so (equation-iii) can be written as

$$F = \frac{\frac{1}{2}mv^2 - \frac{1}{2}mu^2}{s} \qquad \text{...(iv)}$$

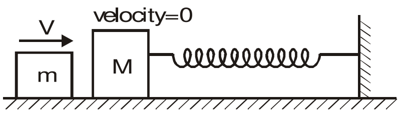
Equation (iv) gives us the relationship between force & energy.

The difference between the final and initial kinetic energies is the change in K.E. of the body Δ(K.E.)

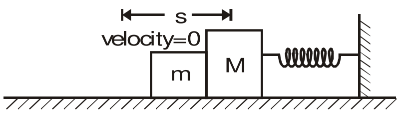
∴ W = change in K.E. = Δ(K.E.)

POTENTIAL ENERGY

The energy possessed by an object by virtue of its position or configuration is called its potential energy. It is measured by the work that the object can do in passing from its present position or configuration to some standard position or configuration (known as zero position or zero configuration)



(a)



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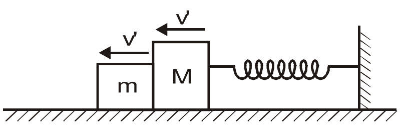
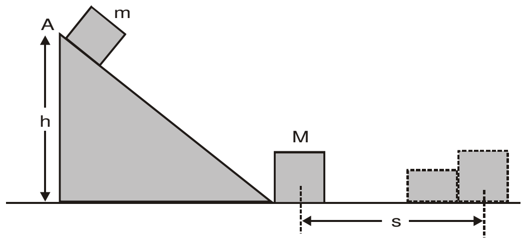


(c)

The kinetic energy of mass m converts into elastic potential energy of spring.

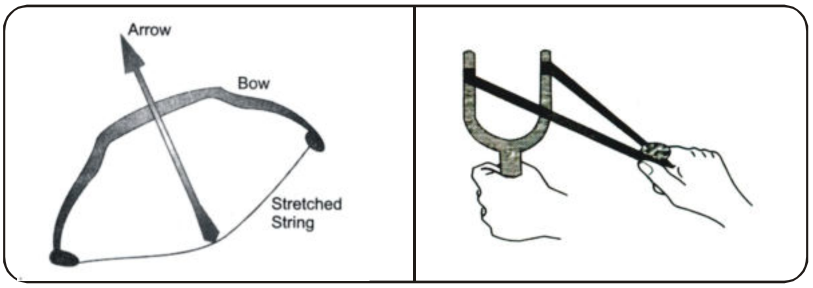
Let us take an example :- Let a small mass m be released from a smooth inclined plane. Another mass M is kept at a rough horizontal plane at rest. The mass m will move along the inclined plane and strike the mass M. Both the masses will move along the horizontal surface for some distance and come to rest. The mass M moves a distance s by the force applied by m. Thus, m does work for which it requires energy. This energy is possessed by m at A as it was at a height h from the horizontal surface. This energy due to position is called potential energy. Precisely speaking this energy is called **gravitational potential energy**.



The gravitational potential energy of mass m doing work

Thus potential energy is defined as follows :

The energy possessed by a body due to its position or change in shape is called potential energy.



NOTE : The energy possessed by a body due to its height from the surface of earth is called gravitational potential energy and that due to change in shape is called elastic potential energy.

Other examples where elastic potential energy is stored are :

(i) a stretched bow

(ii) a stretched rubber band

(iii) a wound spring

All above examples are because of change in shape.

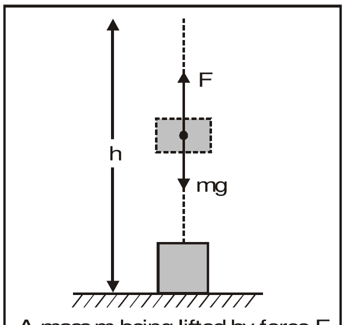
EXPRESSION FOR GRAVITATIONAL POTENTIAL ENERGY

Let us consider a block of mass m kept on the surface of earth. Let the block be lifted to a height h. For that a force F is required which is equal to mg.

This force lifts the block through a distance h. The work done by this force,

$$W = F \times h$$

$$\therefore \quad W = mg \times h \qquad [\because F = mg]$$



A mass m being lifted by force F

This work is converted into potential energy (P.E.) of the block.

$$P.E = mgh$$

The expression shows that potential energy depends on

(a) mass m

(b) height h from ground

(c) acceleration due to gravity g

TRANSFORMATION OF ENERGY

We have discussed various forms of energy available to us. We convert energy from one form to another. Given by following examples.

1. **CONVERSION OF MECHANICAL ENERGY INTO ELECTRICAL ENERGY**. The potential energy of water stored in a dam is changed to kinetic energy when it falls from a height. This kinetic energy rotates a turbine to produce electric energy.

2. **CONVERSION OF ELECTRICAL ENERGY INTO MECHANICAL ENERGY**. An electric motor uses electrical energy to run various electrical appliances, e.g., a train, a fan, washing machine, mixer, grinder etc.

3. **CONVERSION OF ELECTRICAL ENERGY INTO HEAT ENERGY**. In an electric heater, a geyser, a toaster, an oven etc., electric energy is changed to heat energy.

4. **CONVERSION OF HEAT ENERGY INTO MECHANICAL ENERGY**. In heat engines (e.g., a steam engine), heat energy changes to mechanical energy.

5. **CONVERSION OF ELECTRICAL ENERGY INTO LIGHT ENERGY.** In an electric bulb, a fluorescent tube, a flood light etc., electrical energy is changed to light energy.

6. **CONVERSION OF ELECTRIC ENERGY INTO SOUND ENERGY**. An electric bell, a stereo, a loudspeaker etc., change electric energy into sound energy.

7. **CONVERSION OF CHEMICAL ENERGY INTO HEAT ENERGY.** When fuels are burnt, chemical energy gets converted into heat energy.

8. **CONVERSION OF ELECTRICAL ENERGY INTO CHEMICAL ENERGY.** When a battery is charged, electrical energy changes into chemical energy. An inverter in our home does the same thing.

9. **CONVERSION OF SOUND ENERGY TO ELECTRICAL ENERGY.** A microphone converts sound energy into electrical energy.

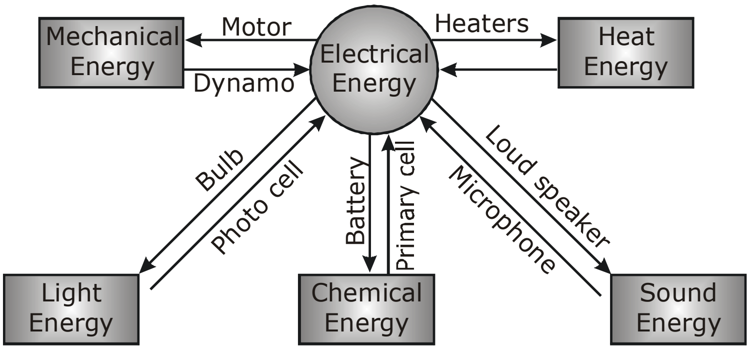
10. **CONVERSION OF CHEMICAL ENERGY TO ELECTRICAL ENERGY.** An electric cell converts chemical energy into electrical energy.

11. **CONVERSION OF LIGHT ENERGY INTO ELECTRIC ENERGY.** A solar cell converts light energy into electrical energy.

12. **CONVERSION OF CHEMICAL ENERGY INTO MECHANICAL ENERGY.** In automobiles, chemical energy of petrol, diesel or CNG (compressed natural gas) is converted into mechanical energy.

13. **CONVERSION OF LIGHT ENERGY INTO CHEMICAL ENERGY.** In photosynthesis, light energy .from the Sun is absorbed by green plants and is converted to chemical energy.

14. **CONVERSION OF NUCLEAR ENERGY INTO ELECTRICAL ENERGY.** Nuclear power. plants are used to generate electrical energy from nuclear energy.



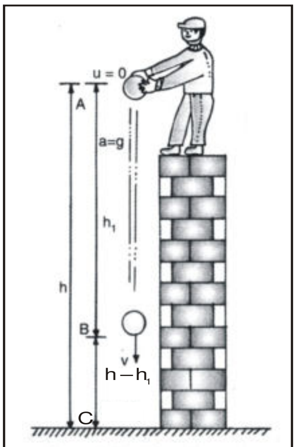
Some Energy Transformations

Some man made devices which convert one form of energy into another are is given as follows.

	DEVICE	INPUT ENERGY	OUTPUT ENERGY
1.	Fan	Electrical energy	Kinetic energy
2.	Electric lamp	Electrical energy	Light energy
3.	Electrical heaters	Electrical energy	Heat energy
4.	Radio	Electrical energy	Sound energy
5.	Water pump	Electrical energy	to kinetic energy of impeller to potential energy of water
6.	Cell Chemical energy	Electrical energy	
7.	Microphone	Sound energy	Electrical energy
8.	Rechargeable cell	(a) During discharging Chemical energy	(a) Electrical energy
		(b) During charging Electrical energy	(b) Chemical energy
9.	Loudspeaker	Electrical energy	Sound energy
10.	Elevator moving up	Electrical energy	Potential energy
11.	Television	Electrical energy	Sound energy, light energy
12.	Thermal power plant	Chemical energy of coal	Electrical energy
13.	Car	Chemical energy of petrol/diesel	Mechanical energy
14.	Nuclear power plant	Nuclear energy	Electrical energy
15.	Solar cell	Solar energy	Electrical energy
16.	Watch	Potential energy of wound spring	K.E. of hands of watch
17.	Generator	Kinetic energy	Electrical energy

LAW OF CONSERVATION OF ENERGY

According to law of conservation of energy, energy can neither be created nor destroyed, it can be converted from one form to another.



Conservation of mechanical energy in free fall

Let us consider two cases where mechanical energy is conserved.

CASE : A ball is dropped from some height.

At point A: Let a ball of mass m is dropped from a height h. Here the total energy (T.E.) of the ball is the sum of kinetic energy (K.E.) and potential energy (P.E.).

Potential energy = mgh

Kinetic energy = $\frac{1}{2}$ m $(0)^2 = 0$ (u = 0)

$\therefore$ $[T.E.]_A = mgh + 0 = mgh$ ... (A)

At point B: Let the ball travel a distance of h_1 in time t during its fall. Then the velocity of the ball after time t can be found by using equation of motion. $u = 0$, $a = g$, $S = h_1$, $v = v$

Using $v^2 - u^2 = 2as$

$v^2 - u^2 = 2gh_1$

$\Rightarrow$ $v^2 = 2gh_1$

Now K.E. at B = $\frac{1}{2}mv^2 = \frac{1}{2}m \times 2gh_1 = mgh_1$

P.E. at B = $mg(h - h_1)$

Total energy at B = K.E. + P.E. = $mgh_1 + mg(h - h_1) = mgh$ ... (B)

At point C : Suppose the ball cover a distance h when it moves from A to C. Let V be the velocity of the ball at point C just before it touches the ground, then

$v^2 - u^2 = 2gh$

$v^2 - 0 = 2gh$ or $v^2 = 2gh$ therefore

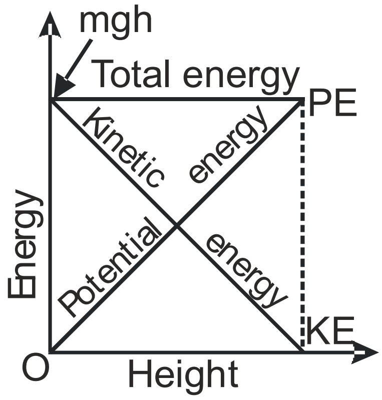
Kinetic energy (K.E.) = $1/2\ mv^2 = 1/2\ m(2gh) = mgh$

and potential energy at C $\therefore$ P.E. = 0

Hence total energy at point C.

E = K.E. + P.E. = mgh + 0 = mgh ... (C)

Thus it is clear from equations A, B and C, that the total mechanical energy of a freely falling ball remain constant. There is, simply, a transformation of mechanical energy. This transformation is depicted in the graph of figure.



Newton's Thought
How does an object with energy do work? **Explanation** An object that possesses energy can exert a force on another object. When this happens, energy is transferred from first object to the second object. The second object may move as it receives energy and therefore do some work. thus, the first object had a capacity to do work. this implies that any object that possesses energy can do work.

POWER

1. POWER OF A MACHINE IS DEFINED AS THE RATE OF WORK DONE BY THE MACHINE.

2. POWER IS DEFINED AS THE RATE OF DOING WORK.

3. POWER OF A MACHINE IS DEFINED AS WORK DONE BY THE MACHINE PER SECOND.

If you lift a block of mass 1 kg through a distance of 1 m in 2 seconds, what is the work done?

$W = F \times s = \; = mg \times h = 1 \times 9.8 \times 1 = 9.8\ J$

If you lift the same block through the same height in 1 minute, what is the work done? The answer comes out to be the same 9.8 J.

What is the work done if the time taken is 5 minutes? The work done is again 9.8 J.

But we are generally interested in time oriented work, i.e., work should be completed in a particular amount of time. The physical quantity which takes care of 'how fast is the work done' is power.

NOTE: If we want to find rate of work done by a man then the word 'machine' can be replaced by 'man'.

$$\boxed{\text{Power} = \frac{\text{Work}}{\text{time}}} \quad \text{or} \quad \boxed{P = \frac{W}{t}}$$

Power is scalar quantity

Unit of power

SI unit of power is watt (W)

1 kW = 1000 W

1 MW (Mega watt) = 10^6 W

1GW(giga watt) = 10^9 W

Another unit of power is horse power (HP).

1 HP = 746W

Definition of Watt

When t = 1 s, W = 1J, then P = 1 W

One watt is the power of a man or a machine capable of doing work at the rate of one joule per second

i.e. $1\ \text{Watt} = \frac{1\,\text{Joule}}{1\,\text{Second}}$ or $W = J\ s^{-1}$

Power in terms of energy :

Since work and energy are interconvertible, therefore,

$$\text{Power} = \frac{\text{Energy}}{\text{time}} \quad \text{or} \quad P = \frac{E}{t} \qquad E = P \times t$$

Also, $W = F \times s$ When displacement is applied in the direction of force

then $P = \frac{W}{t} = F \times \frac{s}{t}$

$\Rightarrow$ $P = F \times v$ This is power in terms of force and velocity.

Average power : Average power of an agent is defined as the ratio of total work done to the total time taken.

$$\text{Average Power} = \frac{\text{total work done}}{\text{total time taken}}$$

◈ **Commercial Unit of Energy : Kilowatt-hour (kwh)**

One kilowatt hour is the amount of energy consumed (or work done) by an agent in one hour working at a constant rate of one kilowatt.

Is kWh a unit of power or energy? The answer is energy.

We can write 1 kWh as 1 kW $\times$ 1h.

Now, since $P = \frac{E}{t}$ $\therefore E = P \times t$

If power is in kW (kilowatt) and time in hour, then the unit of energy is kWh.

The unit kWh is important because this is a commercial unit of energy used by electricity boards. If you enquire from your parents what was the last electricity bill? If the answer is 600 units, it means that you have used 600 kWh of energy during the duration of bill. Thus, you pay for the electrical energy that you use.

Relation between kWh and Joule

1 kWh = 1000 Wh $[\because 1 \text{ kW} = 1000 \text{ W}]$

Now, $1 \text{ W} = 1 \text{ Js}^{-1}$ and $1 \text{ h} = 60 \times 60 \text{ s} = 3600 \text{ s}$

$\therefore$ $1\text{kWh} = 1000 \text{ Js}^{-1} \times 3600 \text{ s} = 3600000 \text{ J} = 3.6 \times 10^6 \text{ J}$

$\therefore$ $1 \text{ kWh} = 3.6 \times 10^6 \text{ J} = 3.6 \text{ MJ}$

NOTE : An energy of 1 kWh is equivalent to using a bulb of 1 kW for 1 hour.

Relationship between kinetic energy and linear momentum:

What can you conclude from the relationship, $\mathbf{K.E.} = \frac{1}{2}\mathbf{mv^2}$

we can conclude as follows :

When the velocity of a body is kept constant, the kinetic energy is directly proportional to the mass of the body, K.E. $\propto$ m

Thus,

If the mass of a body is doubled (v remaining constant), the kinetic energy of the body also gets doubled.

If the mass of the body is reduced to half (v remaining constant), the kinetic energy of the body also gets halved.

The kinetic energy of a body is directly proportional to the square of its velocity (or speed) i.e., K.E. $\propto v^2$

So, $(\because$ m is constant)

If the velocity of a body is doubled, then its kinetic energy increases four times.

If the velocity of a body is reduced to half, then its kinetic energy gets to one-fourth.

How is the kinetic energy of a body related to its momentum:

Let us consider a body of mass m having a velocity v. Then

Momentum of the body $p = \text{Mass} \times \text{velocity} = m \times v$

This gives, $v = \frac{p}{m}$ ... (1)

From definition,

Kinetic energy (K.E.) of the body $= \frac{1}{2} mv^2$ ... (2)

Substituting the value of v from Equation (1) into Equation (2) we can write,

$$K.E. = \frac{1}{2} m \times \frac{p^2}{m^2} = \frac{1}{2} \times \frac{p^2}{m}$$

Then, we can write, $p^2 = 2m \times K.E.$

$$p = \sqrt{2m \times K.E.}$$

Thus, $\text{Momentum} = \sqrt{2 \times \text{mass} \times \text{kinetic energy}}$

Newton's Thought
A light body and a heavy body have same kinetic energy. Which one of the two has greater momentum?
Explanation
Firstly, we will find the relationship between kinetic energy and linear momentum.
Kinetic energy, $E_K = \frac{1}{2}mv^2 = \frac{1}{2}mv^2 \times \frac{m}{m} = \frac{(mv)^2}{2m}$
or $\boxed{E_K = \frac{p^2}{2_M}}$ (p = mv = linear momentum)
or $p^2 = 2mE_K$ or $p = \sqrt{2mE_K}$
This means, if kinetic energy (E_k) is constant for both the bodies, then, $p \propto \sqrt{m}$
Thus, heavier body will have greater momentum than the lighter body.

SOLVED PROBLEMS

Ex.1 A boy pushes a book by applying a force of 40N. Find the work done by this force as the book is displaced through 25 cm along the path.

Sol. Here, force acting on the book, F = 40N

distance through which book is displaced, s = 25 cm = 0·25 m

Work done by the force, i.e., $W = F \times s = (40\ N)\ (0{\cdot}25\ m) = 10J$

Ex.2 A ball of mass 1 kg thrown upwards, reaches a maximum height of 4 m. Calculate the work done by the force of gravity during the vertical displacement. ($g = 10\ m/s^2$).

Sol. Here, force of gravity on the ball, $F = mg = (1\ kg)\ (10\ m/s^2) = 10N$

vertical displacement of the ball, s = 4m

Since the force and the displacement of the ball are in opposite directions, work done by the force of gravity, i.e., $W = -F \times s = -(10N)\ (4m) = -40J$

Obviously, work done against the force of gravity = 40J

Ex.3 Find the amount of work done by a labourer who carries n bricks of m kilogram each to the roof of a house h metre high by climbing a ladder.

Sol. Here, force exerted by the labourer in carrying n bricks (each of mass m kg),

F = (mn) g = (mng) newton

displacement of the bricks, s = h metre

Work done by the labourer, $W = F \times s$ = (mng newton) × (h metre) = mngh joule

Ex.4 An engine pulls a train 1 km over a level track. Calculate the work done by the train given that the frictional resistance is 5×10^5 N.

Sol. Here, frictional resistance, $F = 5 \times 10^5$ N

distance through which the train moves, s = 1 km = 1000 m

Work done by the frictional force, i.e., $W = -Fs = -(5 \times 10^5\ N)\ (1000\ m) = -5 \times 10^8\ J$

(F and s are in opposite directions)

Obviously, work done by the train is 5×10^8 J

Ex.5 A man weighing 70 kg carries a weight of 10 kg on the top of a tower 100 m high. Calculate the work done by the man. ($g = 10\ m/s^2$).

Sol. Here, force exerted by the man, F = (70 + 10) kg wt = 80 kg wt

$= 80 \times 10\ N = 800\ N$ (1 kg wt = 10 N)

vertical displacement, s = 100 m

Work done by the man, i.e., $W = F \times s = (800N)\ (100m) = 80000\ J$

Ex.6 How fast should a man of mass 60 kg run so that his kinetic energy is 750 J ?

Sol. Here, mass of the man, m = 60 kg

kinetic energy of the man, $E_k = 750J$

If v is the velocity of the man, then

$$E_k = \frac{1}{2}mv^2$$

or $$v = \sqrt{\frac{2E_K}{m}} = \sqrt{\frac{2 \times 750J}{60kg}} = 5\ m/s$$

Ex.7 Find the mass of the body which has 5J of kinetic energy while moving at a speed of 2 m/s.

Sol. Here, kinetic energy of the body, $E_k = 5J$

speed of the body, $v = 2$ m/s

If m is the mass of the body, then

$E_k = \frac{1}{2}mv^2$ or $m = \frac{2E_k}{v^2} = \frac{2 \times 5J}{(2m/s)^2} = 2.5$ kg

Ex.8 A player kicks a ball of mass 250 g at the centre of a field. The ball leaves his foot with a speed of 10 m/s, Find the work done by the player on the ball.

Sol. The ball, which is initially at rest, gains kinetic energy due to work done on it by the player.

Thus, the work done by the player on the ball, W = kinetic energy (E_k) of the ball as it leaves his foot, i.e.,

$$W = E_k = \frac{1}{2}mv^2$$

Here, $m = 250\text{ g} = 0{\cdot}25\text{ kg}, v = 10\text{ m/s}$

$$W = \frac{1}{2}(0{\cdot}25\text{kg})\,(10\text{ m/s})^2 = 12{\cdot}5\text{ J}$$

Ex.9 A body of mass 5 kg, initially at rest, is subjected to a force of 20N. What is the kinetic energy acquired by the body at the end of 10s ?

Sol. Here, mass of the body, $m = 5$ kg

initial velocity of the body, $u = 0$

force acting on the body, $F = 20$ N

time for which the force acts, $t = 10$ s

If a is the acceleration produced in the body,

$$a = \frac{F}{m} = \frac{20N}{5kg} = 4\text{ m/s}^2$$

Let v be the velocity of the body after 10 s.

Clearly, $v = u + at = 0 + (4\text{ m/s}^2)\,(10\text{ s}) = 40\text{ m/s}$

Kinetic energy acquired by the body,

$$E_k = \frac{1}{2}mv^2 = \frac{1}{2}(5\text{kg})\,(40\text{m/s})^2 = 4000\text{J}$$

Ex.10 A bullet of mass 20 g moving with a velocity of 500 m/s, strikes a tree and goes out from the other side with a velocity of 400 m/s. Calculate the work done by the bullet in joule in passing through the tree.

Sol. Here, mass of the bullet, $m = 20\text{ g} = 0{\cdot}02$ kg

initial velocity of the bullet, $u = 500$ m/s

final velocity of the bullet, $v = 400$ m/s

If W is the work done by the bullet in passing through the tree, then according to work-energy theorem

$$W = \frac{1}{2}mu^2 - \frac{1}{2}mv^2 = \frac{1}{2}m(u^2 - v^2)$$

or $W = \frac{1}{2}(0{\cdot}02\text{ kg})\,[(500\text{ m/s})^2 - (400\text{m/s})^2] = 900\text{J}$

Ex.11 A body of mass 4 kg is taken from a height of 5 m to a height 10 m. Find the increase in potential energy.

Sol. Here, mass of the body, m = 4 kg

increase in height of the body, h = (10m – 5m) = 5m

Increase in potential energy, E_p = mgh = (4 kg) (10 m/s^2) (5m) = 200J

Aliter. Initial potential energy of the body, E_{pi} = mgh = (4 kg) (10 m/s^2) (5m) = 200J

Final potential energy of the body, E_{pf} = mgh_f = (4 kg) (10 m/s^2) (10 m) = 400J

Increase in potential energy, $E_p = E_{pf} - E_{pi}$ = 400J – 200J = 200J

Ex.12 An object of mass 1 kg is raised through a height h. Its potential energy increases by 1 J. Find the height h.

Sol. Here, mass of the object, m = 1 kg increase in potential energy, E_p = 1J

As E_p = mgh, $h = \frac{E_p}{mg} = \frac{1J}{(1kg)(10m/s^2)} = 0{\cdot}1$ m

Ex.13 A 5 kg ball is thrown upwards with a speed of 10 m/s.

(a) Find the potential energy when it reaches the highest point.

(b) Calculate the maximum height attained by it.

Sol. (a) Here, mass of the ball, m = 5 kg,

speed of the ball, v = 10 m/s

Kinetic energy of the ball, $E_k = \frac{1}{2}mv^2 = \frac{1}{2}(5kg)(10\ m/s)^2 = 250J$

When the ball reaches the highest point, Its kinetic energy becomes zero as the entire kinetic energy is converted into its potential energy (E_p) i.e., E_p = 250J

(b) If h is the maximum height attained by the ball,

E_p = mgh

From eqn. (i) and (ii), mgh = 250J

or $h = \frac{250J}{mg} = \frac{250J}{(5kg)(10m/s^2)} = 5m$

Ex.14 A 5 kg ball is dropped from a height of 10m.

(a) Find the initial potential energy of the ball.

(b) Find the kinetic energy just before it reaches the ground and

(c) Calculate the velocity before it reaches the ground.

Sol. Here, mass of the ball, m = 5 kg

height of the ball, h = 10m

(a) Initial potential energy of the ball,

E_p = mgh = (5 kg) (10 m/s^2) (10m) = 500J

(b) When the ball reaches the ground, its potential energy becomes zero as it is entirely converted into its kinetic energy (E_k), i.e.,

E_k = 500J

(c) If v is the velocity attained by the ball before reaching the ground,

or $E_k = \frac{1}{2}mv^2$

$V = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2 \times 500J}{5kg}} = 14{\cdot}14$ m/s

Ex.15 A body is thrown up with a kinetic energy of 10 J. If it attains a maximum height of 5 m, find the mass of the body.

Sol. Here, kinetic energy of the body, E_k = 10J

maximum height attained by the body, h = 5m

When the body attains maximum height, its entire kinetic energy is converted into its potential energy (E_p)' i.e., $E_p = E_k$

$$mgh = 10J$$

$$m = \frac{10J}{gh} = \frac{10J}{(10 m/s^2)(5m)} = 0.2 \text{ kg}$$

Ex.16 A rocket of mass 3 × 10^6 kg takes off from a launching pad and acquires a vertical velocity of 1 km/s and an altitude of 25 km. Calculate its (a) potential energy (b) kinetic energy.

Sol. Here, mass of the rocket, m = 3 × 10^6 kg

velocity acquired by the rocket, v = 1 km/s = 1000 m/s

height attained by the rocket, h = 25 km = 25000 m

(a) Potential energy of the rocket, E_p = mgh = (3 × 10^6 kg) (10 m/s^2) (25000 m) = **7·5 × 10^{11} J**

(b) Kinetic energy of the rocket,

$$E_k = \frac{1}{2}mv^2 = \frac{1}{2}(3 \times 10^6 \text{ kg})\,(1000 m/s)^2 = \mathbf{1{\cdot}5 \times 10^{12}\ J}$$

Ex.17 A boy of mass 40 kg runs up a flight of 50 steps, each of 10 cm high, in 5 s. Find the power developed by the boy.

Sol. Here, mass of the boy, m = 40 kg

total height gained, h = 50 × 10 cm = 500 cm = 5m

time taken to climb, t = 5s

Work done by the boy, W = mgh = (40 kg) (10 m/s^2) (5m) = 2000J

Power developed, $P = \frac{W}{t} = \frac{2000J}{5s} = 400W$

Ex.18 What should be the power of an engine required to lift 90 metric tonnes of coal per hour from a mine whose depth is 200 m ?

Sol. Here, mass of the coal to be lifted, m = 90 metric tonnes = 90 × 1000 kg=9 × 10^4 kg

height through which the coal is to be lifted, h = 200m

time during which the coal is to be lifted, t = 1h = 60 × 60 = 3600 s

work done to lift the coal, i.e., W = mgh = (9 × 10^4 kg) (10 m/s^2) (200m) = 18 × 10^7J

Power of the engine required i.e., $P = \frac{W}{t} = \frac{18 \times 10^7 J}{3600s}$ = 50000 W = 50 kW

Ex.19 How much time does it take to perform 500J of work at a rate of 10W ?

Sol. Here, work to be performed, W = 500J

rate at which work is to be performed, i.e., power, P = 10W

As $P = \frac{W}{t}$, $t = \frac{W}{P} = \frac{500J}{10W}$ = 50 s

Ex.20 Calculate the units of energy consumed by 100 W electric bulb in 5 hours.

Sol. Here, power of the electric bulb, P = 100 W = 0·1 kW

time for which bulb is used, t = 5h

As $P = \frac{W}{t}$, W = Pt

Energy consumed by the bulb, W = Pt = 0·1 kW (5 h) = 0·5 kWh = 0·5 units

Ex.21 A lift is designed to carry a load of 4000 kg through 10 floors of a building, averaging 6 m per floor, in 10 s. Calculate the power of the lift.

Sol. Total distance covered by the lift, s = 10 × 6 m = 60 m

time in which this distance is covered, t = 10 s

force exerted by the lift, F = 4000 kg wt = 4000 × 10 N

$= 4 \times 10^4$ N (1 kg wt = 10 N)

velocity of the lift, $V = \frac{s}{t} = \frac{60\text{ m}}{10\text{ s}} = 6$ m/ s

Power of the lift, P = F v = $(4 \times 10^4$ N) (6 m/s) = 24×10^4 W = 240 kW

Ex.22 What kind of energy transformation takes place in the following cases ?

(a) When water flowing down a dam runs a turbine to generate electricity.

(b) A running steam engine.

(c) Power generation in a thermal power station.

Ans. ◈ The scheme of energy transformation when water stored in a dam is used to produce electricity is,

Potential energy of water → Kinetic energy of flowing water → Kinetic energy turbine → Electrical energy

Thus, in a hydropower station, the potential energy of water stored in a dam is converted into kinetic energy of the turbine which finally gets converted into electrical energy.

◈ The scheme of energy transformation in a running steam engine is,

Chemical energy of coal → Heat energy of steam → Kinetic energy of moving parts of the engine → Kinetic energy of the engine and boggies.

So, in a running steam engine the scheme of energy transformation is,

Chemical energy → Heat energy → Kinetic energy

◈ The scheme of energy transformation in a thermal power stations is,

Chemical energy of fuel (coal / diesel) → Heat energy of steam → Kinetic energy of turbine → Electrical energy.

Ex.23 A force of 7N acts on an object. The displacement is 8m in the direction of force. The force acts on the object throughout the displacement. What is the work done by the force ?

Sol. F = 7N   s = 8 m

$W = F \times s = 7 \times 8 = 56$ J

Ex.24 A pair of bullocks exert a force of 140 N on a plough. The field being ploughed is 15m long. How much work is done in ploughing the length of the field ?

Sol. $W = F \times s$

$= 140 \times 15$ [The displacement of the plough is along the direction of force exerted by the bullocks]

$= 2100$ J

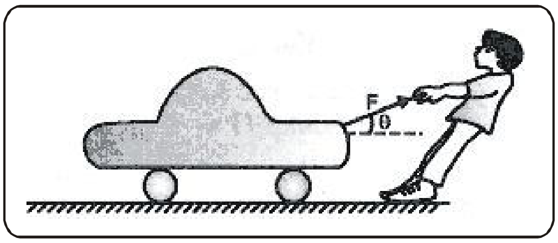
Ex.25 A boy pulls a toy with force of 50N through a string which makes an angle of 30° with the horizontal so as to move the boy by a distance of 1m horizontally. What is the amount of work done ?

Sol. $W = F \times s \times \cos\theta$

$= 50 \times 1 \times \cos 30°$

$= 50 \times \frac{\sqrt{3}}{2}$

$= 25\sqrt{3}$ J



Ex.26 With reference to the above sample problem, if the string were inclined making an angle of 45° with the horizontal, how much pull would he apply along the string to move it through the same distance of 1m? (Given $\cos 45° = 1/\sqrt{2}$)

Sol. Work done is same as above. This is because the horizontal component and the displacement remains the same.

$W = F \times s \times \cos\theta$

$\Rightarrow 25\sqrt{3} = F \times 1 \times \cos 45°$

$\therefore F = 25\sqrt{6} = 61.2$ N

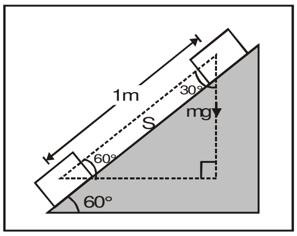
Ex.27 A block of mass 2 kg slides down an inclined plane of inclination 60°. Find the work done by the force of gravity as the block slides through 1m. [Take g = 10 ms^{-2}, cos 30° = $\sqrt{3}$/2].

Sol. As shown in the figure, the angle between the force of gravity mg and displacements is 30°

$W = Fs\cos\theta$

$= mgs\cos\theta$

$= 10\sqrt{3}$ N



VERY SHORT ANSWER TYPE QUESTONS & SOLUTIONS

Q.1 Define the term 'work done'.

Ans. Work done = force × displacement.

Q.2 How much work is done by a man who tries to push the wall of a house but fails to do so.

Ans. $W = FS = 0$ ($\because S = 0$)

Q.3 What is the work done by a student who is reading a book while sitting on a bench ?

Ans. Zero.

Q.4 What is SI unit of work ?

Ans. S.I. unit of work is joule (J).

Q.5 Write the expression for a work done by a force F acting on an object at an angle θ with the displacement S of the object.

Ans. $W = FS \cos \theta$.

Q.6 Is work a scalar or a vector quantity ?

Ans. Work is a scalar quantity.

Q.7 Work done by a force is equal to the product of .... and ....

Ans. The magnitude of force, distance.

Q.8 How is the kinetic energy of a body related to its momentum ?:

Ans. Momentum = $\sqrt{2 \times \text{mass} \times \text{Kinetic energy}}$

Q.9 What is energy ?

Ans. The capacity of doing work by an object is known as the energy of the object.

Q.10 What is SI unit of energy ?

Ans. S.I. unit of energy is joule (J).

Q.11 What type of energy is possessed by a cricket ball just before being caught by a fielder ?

Ans. Kinetic energy.

Q.12 Give an example of an object having elastic potential energy

Ans. A stretched spring or a compressed spring has elastic potential energy.

Q.13 What do you mean by transformation of energy

Ans. The process of converting one form of energy into another form of energy is called transformation of energy.

Q.14 State the energy transformation taking place when a body falls from a certain height.

Ans. Potential energy of a falling body converts into its kinetic energy.

Q.15 A log of wood cut by a saw becomes hot. From where this heat energy comes ?

Ans. Mechanic energy is converted into heat energy.

Q.16 State the law of conservation of energy.

Ans. Energy can neither be created nor be destroyed but can be changed from one form into another form.

Q.17 What is SI unit of power ?

Ans. S.I. unit of power is watt.

Q.18 What is the practical unit of power ?

Ans. Practical unit of power is horse power (H.P.)

Q.19 State the relationship between watt and horse power.

Ans. 1 H.P. = 746 W.

Q.20 A man buys an electric motor of 1 H.P. What is its power in watts ?

Ans. 1 H.P. = 746 W

Q.21 What is the relationship between 'watt' and 'kilowatt' ?

Ans. 1 kilowatt = 1000 watt.

Q.22 Define 1 kWh.

Ans. 1 kWh is the amount of electric energy used by 1000 W electrical appliances in 1 hour.

Q.23 A bus and a car have same kinetic energy. Which of the two is moving fast ? Explain.

Ans. K.E. = $\frac{1}{2}mv^2$ $v = \sqrt{\frac{2K.E.}{m}}$. As K.E. of both bus and the car is same, so, $v \propto \frac{1}{\sqrt{m}}$. Since mass of car is less than that of the bus, so the car is moving faster than the bus.

Q.24 If the speed of a particle is increased four times, how will its kinetic energy be affected ?

Ans. K.E. = $\frac{1}{2}mv^2$. When $v^1 = 4v$ $\therefore$ New (K.E.) = $\frac{1}{2}mv^2 = \frac{1}{2}$ m × 16 v^2 = 16 K.E.

Q.25 The kinetic energy of a body is 10 J. What will be its new kinetic energy when its speed becomes double?

Ans. K.E. = $\frac{1}{2}mv^2$ = 10 J

When $v^1 = 2$ v

$\therefore$ New K.E. = $\frac{1}{2}mv'^2 = \frac{1}{2}$ m × $4v^2$ =4 × $\frac{1}{2}mv^2$ = 4 × 10 J = 40 J

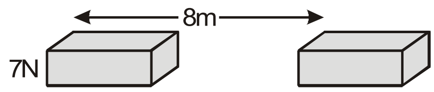
NCERT QUESTIONS WITH SOLUTIONS

Q.1 A force of 7N acts on an object. The displacement is, say 8 m, in the direction of the force. Let us take it that the force acts on the object through the displacement. What is the work done in this case ?

Ans. Force = 7 N

Displacement = 8 m

Work Done = Force × Displacement = 7 × 8 = 56 J



Q.2 When do we say that work is done ?

Ans. Work is said to be done when a force causes displacement of an object in the direction of applied force.

Q.3 Write an expression for the work done when a force is acting on an object in the direction of its displacement.

Ans. Work Done = Force × Displacement i.e., W = F × S

Q.4 Define 1 J of work.

Ans. When a force of 1N causes a displacement of 1 m, in its own direction then work done is said to be one joule.

Q.5 A pair of bullocks exerts a force of 140 N on a plough. The field being ploughed is 15 m long. How much work is done in ploughing the length of the field ?

Ans. Work done= Force × Displacement = 140 × 15 = 2100 J

Q.6 What is the kinetic energy of an object ?

Ans. The energy possessed by a body by virtue of its motion is called kinetic energy.

Q.7 Write an expression for the kinetic energy of an object.

Ans. $KE = \frac{1}{2}mv^2$ where KE → kinetic energy of an object.

'm' – mass of an object.

'v'– velocity.

Q.8 The kinetic energy of an object of mass m, moving with a velocity of 5 ms^{-1} is 25 J. What will be its kinetic energy when its velocity is doubled ? What will be its kinetic energy when its velocity is increased three times?

Ans. Velocity of an object (v) = 5 ms^{-1}

Mass of an object (m) = ?

KE of an object = 25J

We know, $KE = \frac{1}{2} mv^2$

$25 = \frac{1}{2} \times m \times (5)^2$

$\Rightarrow \quad m = \frac{50}{25} = 2$ kg

When the velocity doubles

$KE = \frac{1}{2} mv^2 = \frac{1}{2} \times 2 \times (10)^2 = 100$ J

When the velocity triples

$KE = \frac{1}{2} mv^2 = \frac{1}{2} \times 2 \times (15)^2 = 225$ J

Q.9 What is power ?

Ans. Power is defined as the rate of doing work. It is measured in watt and also in horsepower.

Q.10 Define 1 watt of power.

Ans. When a work of 1 joule is done in 1 s, the power is said to be one watt.

Q.11 A lamp consumes 1000 J of electrical energy in 10 s. What is its power ?

Ans. Power = $\frac{\text{Energy}}{\text{Time}} = \frac{1000}{10} = 100$ W

Q.12 Define average power.

Ans. When a machine or person does different amounts of work or uses energy in different interval of time, the ratio between the total work or energy consumed to the total time is average power.

$$\text{Average Power} = \frac{\text{Total work done or energy consumed}}{\text{Total time}}$$

Q.13 Look at the activities listed below. Reason out whether or not work is done in the light of your understanding of the term 'work'.

- ❑ Suma is swimming a pond.
- ❑ A donkey is carrying a load on its back.
- ❑ A wind-mill is lifting water from a well.
- ❑ A green plant is carrying out photosynthesis.
- ❑ An engine is pulling a train.
- ❑ Food grains are getting dried in the sun.
- ❑ A sailboat is moving due to wind energy.

Ans. (a) Work is done because the displacement of swimmer takes place in the direction of applied force.

(b) If the donkey is not moving, no work is done as the displacement of load does not take place in the direction of applied force.

(c) Work is done, as the displacement takes place in the direction of force.

(d) No work is done, because no displacement takes place.

(e) Work is done, because displacement takes place in the direction of applied force.

(f) No work is done, because displacement does not takes place.

(g) Work is done because displacement takes place in the direction of force.

Q.14 An object thrown at a certain angle to the ground moves in a curved path and falls back to the ground. The initial and the final points of the path of the object lie on the same horizontal line. What is the work done by the force of gravity on the object ?

Ans. Since the object returns to its level of projection, therefore there is no change in its PE. Hence work done by the force of gravity is zero.

Q.15 A battery lights a bulb. Describe the energy changes involved in the process.

Ans. Within the electric cell of the battery the chemical energy changes into electric energy.

The electric energy on flowing through the filament of the bulb, first changes into heat energy and then into the light energy.

Q.16 Certain force acting on a 20 kg mass changes its velocity from 5 ms^{-1} to 2ms^{-1}. Calculate the work done by the force.

Ans. W.D. by the force when velocity is

$$5\ ms^{-1} = \frac{1}{2}mv^2 = \frac{1}{2} \times 20 \times (5)^2 = 250\ J$$

W.D. by the force when velocity is

$$2\ ms^{-1} = \frac{1}{2}\ mv^2 = \frac{1}{2} \times 20 \times (2)^2 = 40\ J$$

Resultant W.D. by the force = Change in KE = 40 – 250 = –210 J

Q.17 A mass of 10 kg is at a point A on a table. It is moved to a point B. If the line joining A and B is horizontal. What is the work done on the object by the gravitational force ? Explain your answer.

Ans. The work done is zero. This is because the gravitational force and displacement are perpendicular to each other.

Q.18 The potential energy of a freely falling object decreases progressively. Does this violate the law of conservation of energy ? Why ?

Ans. It does not violate the law of conservation of energy. Whatsoever, is decrease in PE due to loss of height, same is the increase in the KE due to gain in velocity.

Q.19 What are the various energy transformations that occur when you are riding a bicycle ?

Ans. The chemical energy of the food changes into heat and then to muscular energy. On paddling, the muscular energy changes to mechanical energy.

Q.20 Does the transfer of energy take place when you push a huge rock with all your might and fail to move it? Where is the energy you spend going ?

Ans. Energy transfer does not take place as no displacement takes place in the direction of applied force. The energy spent is used to overcome inertia of rest of the rock.

Q.21 A certain household has consumed 250 units of energy during a month. How much energy is this in joule?

Ans. Energy consumed in a month = 250 units = 250 kWh

= 250 kW × lhr = 250 × 1000W × 3600s = 900,000,000J = 9 × 10^8 J

Q.22 An object of mass 40 kg is raised to a height of 5 m above the ground. What is its potential energy? If the object is allowed to fall, find its kinetic energy when it is half-way down.

Ans. Mass of object (m) = 40 kg

Height (h) = 5 m

Acc. due to gravity (g) = 10 ms^{-2}

∴ PE at a height of 5 m (PE) = mgh = 40 × 10 × 5 = 2000J

PE at a half-way height, i.e., : 2.5 m (PE) = mgh = 40 × 10 × 2.5= 1000 J

Decrease in PE = Increase in KE = 2000 – 1000 = 1000 J.

Q.23 What is the work done by the force of gravity on a satellite moving around the earth ? Justify your answer.

Ans. The W.D. by the force of gravity on the satellite is zero because the force of gravity acts at right angles to the direction of motion of the satellite. Therefore, no displacement is caused in the direction of applied force. The force of gravity only changes the direction of motion of the satellite.

Q.24 Can there be displacement of an object in the absence of any force acting on it ? Think, Discuss this question with your friends and teacher.

Ans. The answer is both Yes or No. Yes because when an object moves in deep space from one point to another point in a straight line, the displacement takes place, without the application of force. No, because force cannot be zero for displacement on the surface of earth i.e., some force is essential.

Q.25 A person holds a bundle of hay over his head for 30 minutes and gets tired. Has he done some work or not ? Justify your answer.

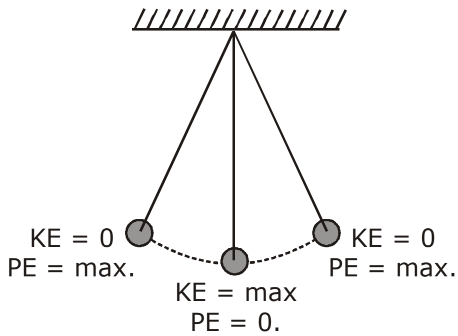
Ans. The person does no work because, no displacement takes place in the direction of applied force as the force acts in the vertically upward direction.

Q.26 An electric heater is rated 1500 W. How much energy does it use in 10 hours ?

Ans. Energy used by heater = Power × Time = 1500 W × 10 h = $\frac{1500 \times 10}{1000}$ = 15 kWh.

Q.27 Illustrate the law of conservation of energy by discussing the energy changes which occur when we draw a pendulum bob to one side and allow it to oscillate. Why does the bob eventually come to rest ? What happens to its energy eventually ? Is it a violation of the law of conservation of energy ?

Ans. When the pendulum bob is pulled (say towards left), the energy supplied is stored in it is in the form of PE on account of its higher position. When the pendulum is released so that it starts moving towards right, then its PE changes into KE, such that in mean position, it has maximum KE, and zero PE. As the pendulum moves towards extreme right, its KE changes into PE; such that at the extreme position, it has maximum PE and zero KE. When it moves from this extreme position to mean position, its PE again changes to KE. This illustrates the law of conservation of energy. Eventually, the bob comes to rest, because during each oscillation a part of the, energy possessed by it transferred to air and in overcoming friction at the point of suspension. Thus, the energy of the pendulum is dissipated in air.



The law of conservation of energy is not violated because the energy merely changes its form and is not destroyed.

Q.28 An object of mass, m is moving with a constant velocity, v. How much work should be done on the object in order to bring the object to rest ?

Ans. W.D. to bring the object to rest = change in KE of the object

$0 - \frac{1}{2}mv^2 = \frac{1}{2}mv^2$

Q.29 Calculate the work required to be done to stop a car of 1500 kg moving at a velocity of 60 kmh^{-1}.

Ans. Mass of car = 1500 kg

Vel. of car = 60 kmh^{-1} = $\frac{60 \times 1000}{60 \times 60}$ = 16.67 ms^{-1}

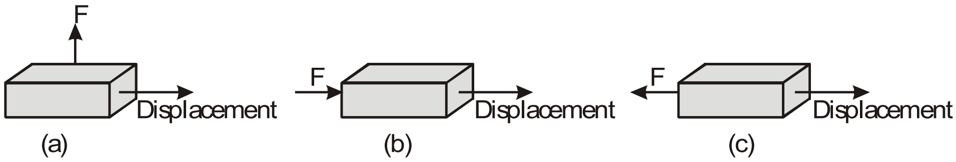
W.D. Change in KE of the car = $K_f - K_i$

$K_i = \frac{1}{2} mv^2 = \frac{1}{2} \times 1500 \times (16.67)^2 = \frac{1}{2} \times 1500 \times 277.89 = 208416.68$ J

Also $K_f = 0$

$\therefore$ W = 0 − 208416.68 = − 208416.68 J

Q.30 In each of the following a force, F is acting on an object of mass, m. The direction of displacement is from west to east shown by the longer arrow. Observe the diagrams carefully and state whether the work done by the force is negative, positive or zero.



Ans. In case of fig (a) W.D. = 0 because the force act in the perpendicular direction of displacement.

In case of fig (b) W.D. is positive, because the force acts in the direction of displacement.

In case of fig (c) W.D. is negative, because the force acts in the direction opposite to the displacement.

Q.31 Soni says that the acceleration in an object could be zero even when several forces are acting on it. Do you agree with her ? Why ?

Ans. Yes, we do agree when the number of forces act on a body, such that they constitute balanced forces, then net force acting on the body is zero. In such a situation no acceleration acts on the object.

Q.32 Find the energy in kWh consumed in 10 hours by four devices of power 500 W each.

Ans. Total power of 4 devices = 4 × 500 = 2000 W = $\frac{2000 \text{ W}}{1000}$ = 2 kW

Time = 10h

$\therefore$ Energy consumed = Power × time = 2 kW × 10 h = 20 kWh

Q.33 A freely failing object eventually stops on reaching the ground. What happens to its kinetic energy ?

Ans. The KE on reaching the ground changes into heat energy, sound energy etc. and therefore gets dissipated in air.

EXERCISE – I BOARD PROBLEMS

Q.1 A player kicks a ball of mass 250 g placed at the centre of a field. The ball leaves his foot with a speed of 8 m/s. Find the work done by the player on the ball.

Q.2 A 10 kg ball is thrown upwards with a speed of 5 m/s. (a) Find its potential energy when it reaches the highest point. (b) Calculate the maximum height it reaches.

Q.3 A body A of mass 3.0 kg and a body B of mass 10 kg are dropped simultaneously from a height of 14.9 m. Calculate (a) their momentum, (b) their potential energies, and (c) their kinetic energies when they are 10 m above the ground.

Q.4 Calculate the work done by a person in lifting a load of 20 kg from the ground and placing it on a 1 m high table.

Q.5 Find the mass of a body which has 5J of kinetic energy while moving at a speed of 2 m/s.

Q.6 The mass of a ball A is double the mass of another ball B. The ball A moves at half the speed of the ball B. Calculate the ratio of the kinetic energy of A to the kinetic energy of B.

Q.7 Calculate the increase in potential energy as a block of 2kg is lifted up through 2m.

Q.8 A ball of mass 200g falls from a height of 5 metres. What is its kinetic energy when it just reaches the ground? ($g = 9.8\ m/s^2$).

Q.9 Find the momentum of a body of mass 100g having a kinetic energy of 20J.

Q.10 How fast should a man of mass 50kg run so that his kinetic energy be 625J ?

Q.11 A horse and a dog are running with the same speed. If the weight of the horse is ten times that of the dog, what is the ratio of their kinetic energies?

Q.12 A ball of mass 0.5 kg slows down from a speed of 5 m/s to that of 3 m/s. Calculate the change in kinetic energy of the ball. State your answer giving proper units.

Q.13 Two bodies having equal masses are moving with uniform speeds of v and 2v respectively. Find the ratio of their kinetic energies.

Q.14 What is the kinetic energy of a body of mass 1 kg moving with a speed of 2 m/s ?

Q.15 A body of 2 kg falls from rest. What will be its kinetic energy during the fall at the end of 2 s ? (Assume $g = 10\ m/s^2$)

Q.16 A man drops a 10 kg rock from the top of a 5 m ladder. What is its speed just before it hits the ground ? What is its kinetic energy when it reaches the ground ? ($g = 10\ m/s^2$)

Q.17 A boy weighing 40 kg makes a high jump of 1.5 m.
(i) What is his kinetic energy at the highest point?
(ii) What is his potential energy at the highest point? ($g = 10\ m/s^2$).

Q.18 To what height should a box of mass 150 kg be lifted, so that its potential energy may become 7350 joules? ($g = 9.8\ m/s^2$).

Q.19 A body of mass 2kg is thrown vertically upwards with an initial velocity of 20 m/s. What will be its potential energy at the end of 2s ? (Assume $g = 10\ m/s^2$).

Q.20 A man is instructed to carry a package from the base camp at B to summit A of a hill at a height of 1200 metres. The man weighs 800N and the package weighs 200N.
(i) How much work does man do against gravity?
(ii) What is the potential energy of the package at A if it is assumed to be zero at B ?

Q.21 Calculate the work done by a student in lifting 0·5 kg book from the ground and keeping it on a shelf 1·5m high.

Q.22 A coolie carries a load of 50kg on his head and walks on a level road upto 100m. What is the work done by him?

Q.23 A crane pulls up a car of mass 500kg to a vertical height of 4m. Calculate the work done by the crane.

Q.24 A boy of mass 55kg runs up a flight of 40 stairs, each measuring 0·15m. Calculate the work done by the boy.

Q.25 A bullet of mass 0·03kg moving with a speed of 400m/s penetrates 12cm into fixed block of wood. Calculate the average force exerted by the wood on the bullet.

Q.26 A bullet of mass 5g travels with a speed of 500m/s. If it penetrates a fixed target which offers a constant resistive force of 1000N to the motion of the bullet, find (a) the initial kinetic energy of the bullet (b) the distance through which the bullet has penetrated.

Q.27 Two bodies of equal masses move with uniform velocities v and 3v respectively. Find the ratio of their kinetic energies.

Q.28 A truck weighing 5000 kg f and a cart weighing 500 kg f are moving with the same speed. Compare their kinetic energies.

Q.29 A bullet of mass 20g is found to pass two points 30m apart in 4s ? Assuming the speed to be constant, find its kinetic energy.

Q.30 A 60kg person climbs stairs of total height 20m in 2min. Calculate the power delivered.

Q.31 The work done by the heart is 1J per beat. Calculate the power of the heart if it beats 72 times/min.

Q.32 A man exerts a force of 200N in pulling a cart at a constant speed of 16m/s. Calculate the power spent by the man.

Q.33 Calculate the power of an engine required to lift 10^5kg of coal per hour from a mine 360m deep.

Q.34 A man does 200J of work in 10s and a boy does 100J of work in 4s. (a) Who is delivering more power? (b) Find the ratio of the power delivered by the man to that delivered by the boy.

FORMATIVE ASSESSMENT

Latest research based questions :

Q.1 Search for different forms of energy for daily use.

Q.2 Using different methods for enhancing the use of energy.

Topics of group discussion / (Internet search)

Q.1 Conserving energy.

Q.2 Alternative sources of energy.

Q.3 "Energy saved is energy produced".

Activity based Questions :-

Q.1 Describe an activity to show that positive work and negative work and done simultaneously when an object is lifted upwards.

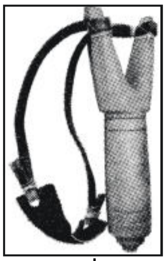
Q.2 Answer to a question based on activity : when an object falls from a certain height, then the gravity and the displacement of the object are in the same direction. Hence, work done by the gravity on the object is positive work done.

Q.3 Think of the situations when an applied force does not produce any displacement in the objects.

Q.4 Wind up a toy car once and place it on the floor.

(a) Did the car move ?
(b) Measure the distance it moved.
(c) Give two, three, four etc., winding and study the distances the car has moved. Explain your findings.

Q.5 Make a catapult. Now hold a small stone n the rubber band, pull it and release.



(a) What do you observe
(b) Now observe the effect of stretching pull on the distance moved by the stone.

FILL IN THE BLANKS :

Q.1 The SI unit of energy is ....

Q.2 Kilowatt hour is a unit of ....

Q.3 The kinetic energy of a body is by virtue of its ....

Q.4 The potential energy of a body is by virtue of its ....

Q.5 Work is said to be done if a force .... a body through a certain distance in the direction of force.

Q.6 Work done is said to be positive if the applied force has a .... in the direction of displacement.

Q.7 Work done is said to be negative if the applied force has a .... in the direction opposite to displacement.

Q.8 Work done is said to be zero if the applied force is .... to the direction of displacement.

Q.9 .... is the SI unit of work.

Q.10 Work done is said to be one joule if a force of one .... displaces a body through a distance of one .... in the direction of force.

Q.11 The .... of a body to do work is called energy.

Q.12 Kinetic energy depends upon the .... and the square of .... of a body.

Q.13 The rate of doing work is called ....

Q.14 Instantaneous power is the product of force and ....

TRUE AND FALSE :

Q.1 When energy changes from one form to another, the energy that disappears from one form, reappears in exactly equivalents amount in the other form.

Q.2 A force does not work, if it produces no motion.

Q.3 Kilowatt hour is the unit of power.

Q.4 Work and Energy have different units.

Q.5 In order to get minimum work, the angle between force and displacement should be 90°.

Q.6 When a body falls on the ground and stops, the principle of conservation of energy is violated.

Q.7 When velocity is halved, its kinetic energy becomes 1/4th.

Q.8 When an arrow is released from a bow, potential energy changes into kinetic energy.

Q.9 Work done by a force depends upon how fast work is done.

Q.10 The rate of doing work is called power.

Q.11 Work done by centripetal force is zero.

Q.12 The unit of work is watt.

Q.13 If we know the speed and mass of an object we can find out its kinetic energy.

MATCH THE SINGLE COLUMN (MATRIX) :

Q.1

	COLUMN-I		COLUMN-II
(A)	Total work done by conservative force.	(p)	Non-zero and negative.
(B)	Total work done by non-conservative force.	(q)	Change in total energy.
(C)	Work done by gravity on a freely falling body.	(r)	Negative.
(D)	Work done by friction on a sliding body.	(s)	Positive.

Q.2

	COLUMN-I		COLUMN-II
(A)	Motor.	(p)	Light into electrical energy.
(B)	Inverter	(q)	Electrical into mechanical energy.
(C)	Loudspeaker.	(r)	Electrical into chemical energy.
(D)	Photocell.	(s)	Electrical into sound energy.

DOUBLE COLUMN (MATRIX) :-

Q.3

	COLUMN-I		COLUMN-II
(A)	Work done by a force during climbing.	(p)	Zero.
(B)	Total work done.	(q)	Change in kinetic energy.
(C)	Total work done in a closed loop.	(r)	Positive.
(D)	Total work done by a force.	(s)	Negative.

Q.4

	COLUMN-I		COLUMN-II
(A)	Net force.	(p)	Energy / distance.
(B)	Conservative force.	(q)	Energy / Time.
(C)	Total power.	(r)	Mass x acceleration.
(D)	Force × velocity	(s)	Power / velocity.

ANSWER KEY

1. 8 J **2.** (a) 125 J (b) 1.25 m
3. (a) 29.4 kg m/s, 98 kg m/s (b) 300 J, 1000 J (c) 144 J, 480 J
4. 196 J **5.** m = 2.5 kg **6.** 1 : 2
7. 40 J **8.** 9.8 J **9.** 2 kg m/s
10. 5 m/s **11.** 10 : 1 **12.** 4 J
13. 1 : 4 **14.** 2 J **15.** 400 J
16. 500 J and 10m/s
17. (i) zero (ii) 600 J **18.** h = 5m
19. 20 m, 400 J
20. (i) 1200000 J (ii) 24×10^4 J **21.** 7·5 J
22. zero **23.** 20000J **24.** 3300J
25. 2×10^4 N
26. (a) 625 J (b) 0·625 m **27.** 1 : 9
28. 10 : 1 **29.** 0·5625J **30.** 100 W
31. 1·2 W **32.** 3·2 kW **33.** 100 kW
34. (a) The boy delivers more power (b) 4/5

FILL IN THE BLANKS :

1. Joule **2.** Energy
3. Motion **4.** Position
5. Displaces **6.** Component
7. Component **8.** Perpendicular
9. Joule **10.** Newton, metre
11. Capactiy **12.** Mass, Velocity
13. Power **14.** Velocity

TRUE AND FALSE :

1. T **2.** T **3.** F **4.** F
5. T **6.** F **7.** T **8.** T
9. F **10.** T **11.** T **12.** F
13. T

MATCH THE COLUMN :

1. (A – q), (B – p), (C – s), (D – r)
2. (A – q), (B – r), (C – s), (D – p)
3. (A – p, r, s), (B – p, q, r, s), (C – p), (D – p, q, r, s)
4. (A – p, r, s), (B – p), (C – q), (D – q)

EXERCISE – II OLYMPIAD QUESTIONS

Q.1 No work is done when an object moves:
(A) along the direction of force
(B) opposite to the direction of force
(C) at any angle to the direction of force
(D) at 90° to the direction of force.

Q.2 Capacity of doing work is called:
(A) power (B) momentum
(C) energy (D) force.

Q.3 Energy possessed by a body on account of position or configuration is called
(A) kinetic energy
(B) potential energy
(C) mechanical energy
(D) magnetic energy.

Q.4 Energy possessed by a body on account of its motion is called:
(A) mechanical energy
(B) potential energy
(C) kinetic energy
(D) magnetic energy.

Q.5 A stone rolls down an inclined plane. Midway during the motion, the stone has:
(A) only kinetic energy
(B) only potential energy
(C) both kinetic and potential energy
(D) neither potential nor kinetic energy.

Q.6 An aeroplane flying at a height of 20,000 m at a speed of 300 kmh^{-1} has:
(A) only potential energy
(B) only kinetic energy
(C) both, potential and kinetic energy
(D) none of the above.

Q.7 A stone is placed on the top of a building of height 'h'. Its potential energy is directly proportional to its:
(A) mass
(B) height
(C) acceleration due to gravity
(D) all the above.

Q.8 If a body is raised through height 'h' on the surface of earth and the energy spent is E, then for the same amount of energy the body on the surface of moon will rise through the height of:
(A) 2h (B) 6h
(C) 4h (D) 12h

Q.9 The kinetic energy of a body is directly proportional to its:
(A) mass (B) velocity
(C) $(velocity)^2$ (D) both (A) and (C)

Q.10 A ball is thrown upward from a point P, reaches to the highest point Q :
(A) kinetic energy at P is equal to kinetic energy at Q
(B) potential energy at P is equal to kinetic energy at Q
(C) kinetic energy at P equal to potential energy at Q
(D) potential energy at P is equal to potential energy at Q

Q.11 Two stones of masses I kg and 2 kg are dropped simultaneously from the same height. Both the stones during free fall have:
(A) momentum
(B) same potential energy
(C) same kinetic energy
(D) same acceleration.

Q.12 When the speed of a particle is increased 3 times, its kinetic energy:
(A) increases 3 times
(B) remains same
(C) increases 9 times
(D) decreases to 1/3.

Q.13 A force of 7N acts on an object through a distance of 8m in its own direction. The work done is :
(A) 7J (B) 8J
(C) 56J (D) 65J

Q.14 A pair of bullocks exert a force of 140N on a plough through distance of 15 m. The work done by the bullocks is:
(A) 280J (B) 1400J
(C) 2100J (D) 21000J

Q.15 The kinetic energy of an object of mass 'm', moving with a velocity of 5 ms^{-1} is 25 J. If the velocity is increased by three times, the kinetic energy is :
(A) 100J (B) 225J
(C) 400J (D) 180J

Q.16 An electric lamp consumes 1000 J of electric energy in 10 second. The power of lamp is :
(A) 10 W (B) 50 W
(C) 100 W (D) 1000 W.

Q.17 A body of mass 20 kg, slows down from 5 ms^{-1} to 2 ms^{-1} by a retarding force. The work done by the force is:
(A) –50J (B) –200J
(C) –300J (D) –210J

Q.18 A mass of 10 kg at point A on a table is moved to point B. If the line joining the A and B is horizontal, the work done by the body is : [a = 10 ms^{-2}]
(A) 10 kg × AB (B) 10N × AB
(C) 100N × AB (D) 50N × AB.

Q.19 A certain household consumes 250 units of electric energy in a House. The energy consumed in mega joule is:
(A) 900 MJ (B) 750 MJ
(C) 2250 MJ (D) 1750 MJ.

Q.20 An object of mass 40 kg (g = 10 ms^{-2}) is raised to a height of 8 m above the ground. The gain potential energy by the object:
(A) 200J (B) 3200J
(C) 1500J (D) 1000J.

Q.21 An electric heater is rated 1500 W. The energy used by it in 10 hours is :
(A) 5 kWh (B) 10 kWh
(C) 15 kWh (D) 20 kWh.

Q.22 An object of mass m is moving with a constant velocity 'u'. The work done on the object to bring it to rest is :
(A) mv^2 (B) ½ mv^2
(C) mv (D) $\frac{m^2v}{2}$

Q.23 A car of mass 1500 kg is moving with a velocity of 60 kmh^{-1}. The work done by its brakes to bring it to rest is:
(A) 208.42 kJ (B) 198.52 kJ
(C) 112.42 kJ (D) 212.52 kJ

Q.24 The energy consumed (in kWh) by four devices of 500W each in 10 hours is :
(A) 4 kWh (B) 5 kWh
(C) 10 kWh (D) 20 kWh.

Q.25 A locomotive exerts a force of 7500N and pulls a train by 1.5 km. The work done by the locomotive in mega joules is :
(A) 12.25 MJ (B) 11.25 MJ
(C) 10.75 MJ (D) 11.50 MJ

Q.26 A horse does a work of 6250J while applying a force of 250N in pulling a tonga. The displacement produce in tonga is :
(A) 12.5m (B) 15m
(C) 25m (D) 20m.

Q.27 A work of 60 J done by a force F, which causes a displacement of 2 m. The magnitude of force F is :
(A) 120N (B) 60N
(C) 30N (D) 45N.

Q.28 The work done by an electric drill rated 50 W in 30s is :
(A) 1200J (B) 600J
(C) 900J (D) 1500J.

Q.29 Find the work done by a force of 5N to displace a book through 20 cm along the direction of the push.
(A) 3.0 J (B)5.0J
(C) 1.0 J (D)4.0J

Q.30 A ball of mass 1 kg thrown upwards reaches a maximum height of 5.0 m. Calculate the work done by the force of gravity during this vertical displacement.
(A) – 59J (B) – 49J
(C) – 30J (D) – 48J

Q.31 A person pulls a body on a horizontal surface by applying a force of 5.0 N at an angle of 30° with the horizontal. Find the work done by this force in displacing the body through 2.0 m.
(A) 5 $\sqrt{3}$ J (B) 6 $\sqrt{2}$ J
(C) 7 $\sqrt{3}$ J (D) 4 $\sqrt{3}$ J

Q.32 An object of mass 1 kg is raised through a height 'h'. Its potential energy is increased by 1 J. Find the height 'h'.
(A) 0.102 m (B) 0.105 m
(C)0.130m (D) 0.110m

Q.33 The kinetic energy of a ball of mass 200 g moving at a speed of 20 cm/s is:
(A) 0.005 J (B) 0.004 J
(C) 0.001 J (D) 0.007 J

Q.34 The work done by a student in lifting a 0.5 kg book from the ground and keeping it on a shelf of height 1.5 m is :
(A) 8.30 J (B)7.35J
(C) 5.40 J (D) 6.45 J

Q.35 A block of mass 1 kg slides down on an inclined plane of inclination 30°. Find the work done by the weight of the block as it slides through 50 cm.
(A) 3.45 J (B) 5.30 J
(C) 2.45 J (D) 3.50 J

Q.36 A force of 10 N displaces an object through 20 cm and does work of 1 J in the process. Find the angle between the force and displacement.
(A) $\theta = 60°$ (B) $\theta = 30°$
(C) $\theta = 35°$ (D) $\theta = 45°$

Q.37 A body of mass 0.5 kg is taken to a height R_e. above the earth's surface, where R_e is the radius of the earth. If the body is now raised through a height of 2 m, what is the increase in its potential energy?
(A) 2.45 J (B) 5.45 J
(C) 6.35 J (D) 8.30 J

Q.38 A ball is dropped from a height H. When it reaches the ground, its velocity is 40 m/s. Find the height?
(A) 71.6 m (B) 32.5 m
(C) 81.6 m (D) 51.6 m

Q.39 How much time will it take to perform 440 J of work at a rate of 11 W?
(A) 50 s (B) 40 s
(C) 30 s (D) 20 s

Q.40 When the speed of a particle is doubled, its kinetic energy
(A) remains the same
(B) gets doubled
(C) becomes half
(D) becomes four times

Q.41 When the speed of a particle is doubled, the ratio of its kinetic energy to its momentum
(A) remains the same
(B) gets doubled
(C) becomes half
(D) becomes four times

Q.42 A person A does 500 J work in 10 minutes and another person B does 600 J of work in 20 minutes. Let the power delivered by A and B be P_1 and P_2 respectively, then
(A) $P_1 = P_2$
(B) $P_1 > P_2$
(C) $P_1 < P_2$
(D) P_1 and P_2 are undefined

Q.43 By what factor does the kinetic energy of a particle increase if the velocity is increased by a factor of three?
(A) 6 (B) 7
(C) 8 (D) 9

Q.44 A block is thrown upwards with a kinetic energy 1 J. If it goes up to a maximum height of 1 m, then the mass of the block is :
(A) 110 g (B) 100 g
(C) 105 g (D) 104 g

Q.45 Two persons do the same amount of work, one in 10 s and the other in 20 s. Find the ratio of the power used by the first person to that by the second person.
(A) 6 (B) 2
(C) 5 (D) 4

Q.46 Calculate the velocity of the bob of a simple pendulum at its mean position if it is able to rise to a vertical height of 10 cm. (Given : g = 980 cms^{-2})
(A) 1.40 ms^{-1} (B) 2.54 ms^{-1}
(C) 3.43 ms^{-1} (D) 5.35 ms^{-1}

Q.47 A one kilowatt motor pumps out water from a well 10 metres deep. Calculate the quantity of water pumped out per second.
(A) 10.204 g (B) 15.302 g
(C) 11.201 g (D) 16.204 g

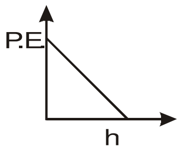
Q.48 Which of the following equations show the correct relationship between mass, momentum and kinetic energy?
(A) $P = \sqrt{2mE_k}$ (B) $P = \sqrt{5mE_k}$
(C) $P = \sqrt{4mE_k}$ (D) $P = \sqrt{6mE_k}$

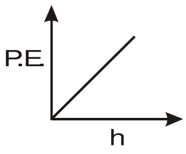
Q.49 A light body and a heavy body have the same kinetic energy. Which one will have a greater momentum?
(A) Lighter body
(B) Heavier body
(C) Both bodies have same momentum
(D) None of the above

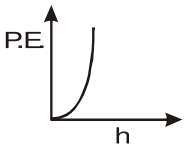
Q.50 The momentum of a body is numerically equal to the kinetic energy of the body. What is the velocity of the body?
(A) $\frac{1}{\sqrt{2}}$ units (B) 2 units
(C) $\frac{1}{\sqrt{3}}$ units (D) $\sqrt{3}$ units

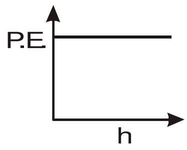
Q.51 A car is accelerated from 10 ms^{-1} to 15 ms^{-1}. The increase in kinetic energy is E_{k_1}. Again, the car is accelerated from 15 ms^{-1} to 20 ms^{-1}. The increase in kinetic energy is now E_{k_2}. What is the ratio of $\frac{E_{k_1}}{E_{k_2}}$?
(A) 0.5. (B) 0.7
(C) 0.1 (D) 0.4

Q.52 If a graph between P.E. of the body in relation to the height through which it falls freely is plotted, it may be noted that the total energy remains the same. Which of the following graphs shows this relation correctly?

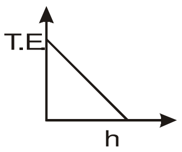
(A) 

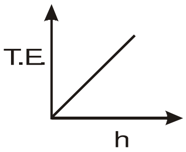
(B) 

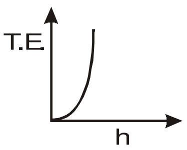
(C) 

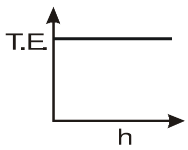
(D) 

Q.53 A graph of the total energy, (P.E + K.E.) of a freely falling body from a height is plotted. Which of the following is the best approximation?

(A) 

(B) 

(C) 

(D) 

Q.54 A girl of mass 40 kg climbs 50 stairs of average height 20 cm each in 50 s. The power of the girl is : (g = $10 ms^{-2}$)
(A) 50 W (B) 50×20 W
(C) 80 W (D) $50 \times 20 \times 2$W

Q.55 When a light and a heavy body have equal K.E, then which one has a greater momentum?
(A) light body
(B) heavy body
(C) both have equal momentum
(D) uncertain

Q.56 In SI system, the unit of P.E. is
(A) erg (B) dyne-cm
(C) J (D) none of these

Q.57 Kilowatt hour (kWh) represents the unit of
(A) power (B) impulse
(C) momentum (D) none of these

Q.58 When speed of a motor car increases six times, then kinetic energy increases by
(A) 6 times (B) 36 times
(C) 12 times (D) 24 times

Q.59 1 kWh equals
(A) 36×10^2 Joules (B) 36×10^4 Joules
(C) 3.6×10^6 Joules (D) none of these

Q.60 When speed of the moving object is doubled its
(A) acceleration is doubled
(B) momentum becomes four times more
(C) K E. is increased to four times
(D) potential energy is increased

Q.61 When time taken to complete a given amount of work increases, then
(A) power increases (B) power decreases
(C) energy increases (D) energy decreases

Q.62 When the force applied and the displacement of the body are inclined at 90° with each other, then work done is
(A) infinite (B) maximum
(C) zero (D) unity

Q.63 The KE. of a body in increased most by doubling its
(A) mass (B) weight
(C) speed (D) density

Q.64 If a force F is applied on a body and it move with velocity v, then power will be :-
(A) F x v (B) $\frac{F}{v^2}$
(C) $\frac{F}{v}$ (D) $F \times v^2$

Q.65 Work done by a centripetal force
(A) increases by decreasing the radius of the circle
(B) decreases by increasing the radius of the circle
(C) increases by increasing the mass of the body
(D) is always zero

Q.66 A 1 kg mass falls from a height of 10 m into a sand box. What is the speed of the mass just before hitting the sand box? If it travels a distance of 2 cm into the sand before coming to rest, what is the average retarding force?
(A) 12 m/sec and 3600N
(B) 14 m/sec and 4900N
(C) 16 m/sec and 6400N
(D) 18 m/sec and 8100N

Q.67 Work done in moving a 50 kg block through a horizontal distance of 10 m by applying a force of 100N which makes an angle of 60° with the horizontal is
(A) 200 joule (B) 425 joule
(C) 500 joule (D) 575 joule

Q.68 kWh is the unit of
(A) force (B) power
(C) time (D) energy

Q.69 An elevator is designed to lift a load of 1000 kg through 6 floors of a building averaging 3·5 m per floor in 6 sec. Power of the elevator, neglecting other losses, will be
(A) $3{\cdot}43 \times 10^4$ watt (B) $4{\cdot}33 \times 10^4$ watt
(C) $2{\cdot}21 \times 10^4$ watt (D) $5{\cdot}65 \times 10^4$ watt

Q.70 The work done by a body is directly proportional to :
(A) force acting on the body
(B) displacement produced in the body
(C) mass of the body
(D) both (A) and (B)

Q.71 Work done is said to be positive when a force causes displacement:
(A) in its own direction
(B) in the direction opposite to the applied force
(C) in the direction at right angles to the direction of applied force
(D) none of the above.

Q.72 Work done is said to be negative, when a force causes displacement:
(A) in the direction opposite to the direction of applied force
(B) in the direction of applied force
(C) in the direction opposite to the direction of applied force
(D) none of the above.

Q.73 In which case work is not done:
(A) a girl swimming in a pond
(B) a windmill lifting water from a well
(C) a standing man holding a suit case in his hand
(D) a sail boat moving in the direction of wind.

Q.74 In which case work is done:
(A) a green plant carrying out photosynthesis
(B) a porter standing at a place and carry heavy load on his head
(C) drying of food grains in sun
(D) a trolley rolling down a slope

Q.75 A stone is tied to a string and whirled in a circular path. The work done by the stone is :
(A) negative (B) zero
(C) positive (D) none of the above.

Q.76 A man carries a suitcase in his hand climbs up the stairs. The work done by the man is :
(A) positive (B) negative
(C) zero (D) none of the above.

Q.77 A rocket rises up in the air due to the force generated by the fuel. The work done by the:
(A) fuel is negative work and that of force of gravity is positive work
(B) fuel is positive work and that of force of gravity is negative work
(C) both fuel and force of gravity do positive work
(D) both fuel and force of gravity do negative work.

Q.78 One joule work is said to be done when a force of one newton acts through a distance of:
(A) 1 cm (B) 1 mm
(C) 1 m (D) 1 km

Q.79 Work is the product of time and:
(A) power (B) energy
(C) force (D) acceleration.

Q.80 In angle in between the direction of applied force and displacement, for maximum work should be :
(A) 90° (B) 45°
(C) zero (D) 30°

Q.81 Work done upon a body is: **[NTSE]**
(A) a vector quantity (B) a scalar quantity
(C) always positive (D) always negative

Q.82 In the SI system the unit of P.E. is: **[NTSE]**
(A) erg (B) dyne-cm
(C) J (D) none of these

Q.83 Kilowatt hour (kWh) represents the unit of:
(A) power (B) impulse **[NTSE]**
(C) momentum (D) none of these

Q.84 Two unequal masses possess the same K.E. Then, the heavier mass has: **[NTSE]**
(A) grater momentum
(B) smaller momentum
(C) the same momentum as the lighter mass
(D) greater speed

Q.85 Two unequal masses possess the same momentum, then the kinetic energy of the heavier mass is __________ the kinetic energy of the lighter mass. **[NTSE]**
(A) same as (B) greater than
(C) smaller than (D) much greater than

Q.86 The speed of a motor car becomes six times, then the kinetic energy becomes: **[NTSE]**
(A) 6 times (B) 36 times
(C) 12 times (D) 24 times

Q.87 The number of joules contained in 1 kWh is: **[NTSE]**
(A) 36×10^2 (B) 36×10^3
(C) 36×10^4 (D) 3.6×10^6

Q.88 A body moves through a distance of 3 m in the following different ways. In which case is the maximum work done? **[NTSE]**
(A) when pushed over an inclined plane
(B) when lifted vertically upward
(C) when pushed over smooth rollers
(D) when pushed on a plane horizontal surface

Q.89 In the above example, the work done is minimum when the body is: **[NTSE]**
(A) pushed over an inclined plane
(B) lifted vertically upward
(C) pushed over the smooth rollers
(D) pushed on a plane horizontal surface

Q.90 A truck and a car are moving on a smooth, level road such that the K.E. associated with them is same. Brakes are applied to both of them simultaneously. Which one will cover a greater distance before it stops? **[NTSE]**
(A) car
(B) truck
(C) both will cover the same distance
(D) nothing can be decided

Q.91 A wound watch spring has ____ energy. **[NTSE]**
(A) mechanical (B) kinetic
(C) potential (D) kinetic and potential

Q.92 Two bullets P and Q masses 10 and 20g, are moving in the same direction towards a target with velocities of 20 and 10 m/s respectively. Which one of the bullets will pierce a greater distance through the target? **[NTSE]**
(A) P
(B) Q
(C) both will cover the same distance
(D) nothing can be decided

Q.93 When the time taken to complete a given amount of work increases, then, **[NTSE]**
(A) power increases (B) power decreases
(C) energy increases (D) energy decreases

Q.94 When the force applied and the displacement of the body are inclined at 90° with each other, the work done is: **[NTSE]**
(A) infinite (B) maximum
(C) zero (D) unity

Q.95 A car is moving along a straight level road with constant speed. Then **[NTSE]**
(A) the work done on the car is infinite
(B) the work done on the car is zero
(C) the work done on the car is a measure of the gravitational potential energy
(D) the work done on the car cannot be found

Q.96 Kg m^2 s^{-2} represents the unit of: **[NTSE]**
(A) kinetic energy only
(B) work done only
(C) potential energy only
(D) all the above

Q.97 The moon revolves around the earth because the earth exerts a radial force on the moon. Does the earth perform work on the moon? **[NTSE]**
(A) no (B) yes, sometimes
(C) yes, always (D) cannot be decided

Q.98 The K.E. of a body is increased most by doubling its: **[NTSE]**
(A) mass (B) weight
(C) speed (D) density

Q.99 A body is dropped from a certain height from the ground. When it is halfway down, it possesses, **[NTSE]**
(A) only K.E. (B) both K.E. and P.E.
(C) only P.E. (D) zero energy

Q.100 A body of mass 20 kg is dropped from a height of 2m. If g is taken to be equal to 10 m/s², the kinetic energy of the body, just before striking the ground, will be: **[NTSE]**
(A) 400 J (B) 4 J
(C) 40 J (D) none of these

ANSWER KEY

1.	D	**2.**	C	**3.**	B	**4.**	C
5.	C	**6.**	C	**7.**	D	**8.**	B
9.	D	**10.**	C	**11.**	D	**12.**	C
13.	C	**14.**	C	**15.**	B	**16.**	C
17.	D	**18.**	C	**19.**	A	**20.**	B
21.	C	**22.**	B	**23.**	A	**24.**	D
25.	B	**26.**	C	**27.**	C	**28.**	D
29.	C	**30.**	B	**31.**	A	**32.**	A
33.	B	**34.**	B	**35.**	C	**36.**	A
37.	A	**38.**	C	**39.**	B	**40.**	D
41.	B	**42.**	B	**43.**	D	**44.**	B
45.	B	**46.**	A	**47.**	A	**48.**	A
49.	B	**50.**	B	**51.**	B	**52.**	B
53.	D	**54.**	C	**55.**	B	**56.**	C
57.	D	**58.**	B	**59.**	C	**60.**	C
61.	B	**62.**	C	**63.**	C	**64.**	A
65.	D	**66.**	B	**67.**	C	**68.**	D
69.	A	**70.**	D	**71.**	A	**72.**	A
73.	C	**74.**	D	**75.**	B	**76.**	A
77.	B	**78.**	C	**79.**	A	**80.**	C
81.	B	**82.**	C	**83.**	D	**84.**	A
85.	C	**86.**	B	**87.**	D	**88.**	B
89.	C	**90.**	C	**91.**	C	**92.**	A
93.	B	**94.**	C	**95.**	B	**96.**	D
97.	A	**98.**	C	**99.**	B	**100.**	A

SOUND

CONTENTS IN THE CHAPTER

SOUND

INTRODUCTION

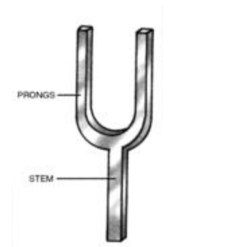
Throughout the day, we listen the various types of sounds like our father's voice, our mother's voice, our teacher's voice, chirping of birds, ringing of a school bell, a telephone ringing, a guitar being played, a siren, a jet engine roaring in the sky, buzzing of a mosquito, a gun shot etc. These sounds stimulate the auditory nerve in the human ear and the brain interprets the sound. Now let us define sound.

Sound is a form of energy which produces the sensation of hearing in our ears.

PRODUCTION OF SOUND

Perform the following activities to produce sound.

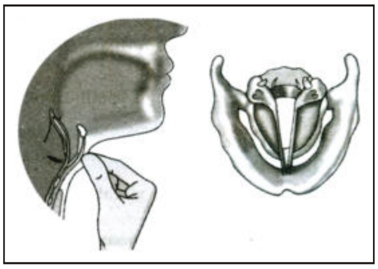
ACTIVITY



Vibrating Tuning Fork

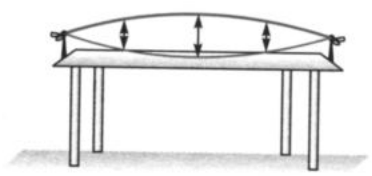
1. Take a plastic scale or ruler from your geometry box. Hold it flat on your desk or table with about half its length protruding (stick out from the surface) over the edge. Now bend it down and release it. It will move up and down rapidly (i.e. it will vibrate) and produce the sound at the same time. The sound will last as long as the vibration (i.e. rapid up and down motion) of the scale continues.

2. Take a tuning fork. Hold it from its stem and strike it with a rubber pad or hammer. You will observe that the prongs of the tuning fork vibrate and at the same time sound is produced (Figure).



3. Place your finger lightly on your throat near the vocal cords as shown in figure. Now say "Ah" for few seconds. You will feel the vibration in your finger as long as you say "Ah".

4. Tie a thin metallic string rigidly at the two ends of a table as shown in figure. Now, pluck the string from the middle and release it. The string begins to vibrate up and down and at the same time, sound is heard.



Conclusion: From these activities, we come to the conclusion that the sound is produced by the vibrating objects or bodies.

PRODUCTION OF SOUND IN MUSICAL INSTRUMENTS

When a drum is beaten, then the skin of drum vibrates and sound is produced. When the strings of a guitar are plucked and released, they vibrate and produce sound. When air is blown into the flute, pipe, clarinet, saxophone etc., it vibrates in the tube of the instrument and hence sound is produced. Sound is also produced when the birds flap their wings during the flight.


Musical Instruments

Newton's Thought
What do you understand by the term vibration or oscillation? Give some examples of vibration you see in your daily life. **Explanation** The vibration (or oscillation) of an object is a cycle or a motion that is repeated over and over with the same time interval each time. A vibration is a cycle in which a particle moves to and from about some equilibrium position (mean position). In such a motion, a particle retraces its path again and again in regular intervals of time. Some examples of vibrations or oscillations we see in our daily life are: (1) A child swinging on a swing. (2) A simple pendulum oscillating about its mean position. (3) An oscillating spring that supports a vehicle.

WHAT IS A WAVE?

The movement of the disturbance through a medium due to the repeated periodic motion of the particles of the medium about their mean positions is known as a wave.

◈ MECHANICAL WAVE

A mechanical wave is a periodic disturbance which requires material medium (i.e. solid, liquid or gas) for its propagation.

In other words, waves that are characterised by the motion of particles of a medium are called mechanical waves.

Examples of mechanical waves

(i) Sound waves in air (ii) Water waves

(iii) Waves produced due to the earthquake (known as seismic waves)

(iv) Waves produced by supersonic jet planes (known as shock waves)

(v) Waves produced in a stretched string. (vi) Waves produced in a slinky or long spring.

TYPES OF WAVES

Waves are of two types : (i) Transverse Wave, (ii) Longitudinal Wave

1. TRANSVERSE WAVE

If the particles of a medium vibrate or oscillate about their mean positions at right angles to the direction of propagation of the disturbance then the wave is called transverse wave.

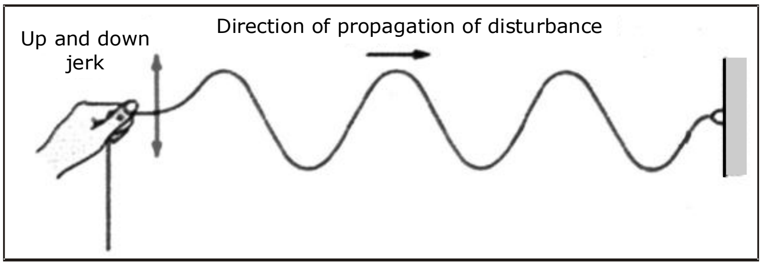
Examples : Movement of string of a sitar or violin, membrane of a tabla or dholak, movement of a kink on a rope.

ACTIVITY

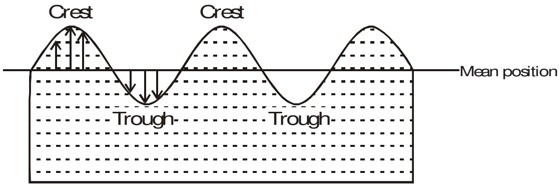
Describe an activity to show the formation of a transverse wave.

Fix one end of a thin rope and give up and down jerk to the free end of the rope.

The rope oscillates or vibrates up and down as shown in figure. The disturbance travels from the free end to the fixed end but the rope vibrates up and down. This wave is known as transverse wave.

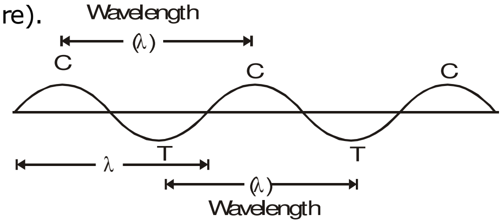


A transverse wave travelling on the surface of water is shown in figure.



When transverse wave travels through the medium, the shape of the medium changes. At some positions, the particles of the medium rise (or elevate) above their mean positions and at some positions, the particles of the medium go down (or depressed) below their mean positions.

The point on the elevation of the medium whose distance from the mean position is maximum is known as **crest** (C). On the other hand, the point on the depression of the medium whose distance from the mean position is maximum is known as **trough** (T). Thus, crests and troughs are formed when a transverse wave travels through a medium (Figure).



WAVELENGTH (OR LENGTH OF A WAVE)

The distance between two successive crests or between two successive troughs is known as the **wavelength** of a transverse wave.

OR

The distance between two successive particles of the medium which are in phase is called **wavelength** of the wave. It is denoted by λ (lambda).

2. LONGITUDINAL WAVE

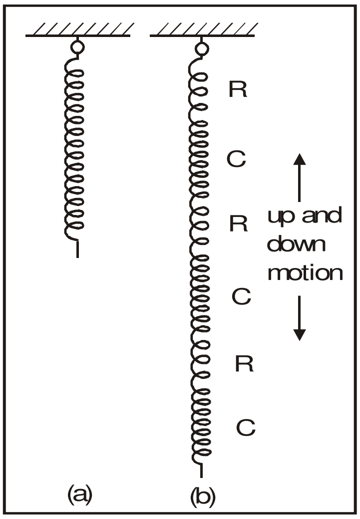
If the particles, of a medium vibrate or oscillate **to and fro** about their mean positions along the direction of propagation of the disturbance then the wave is called **longitudinal wave**.

Examples :- Sound wave, Organ pipes, Vibration on resonance apparatous

ACTIVITY

Describe an activity to show the formation of longitudinal wave.

Take a slinky or a long spring which can be easily compressed and extended as shown in figure (a). Fix one end of the slinky with a rigid support. Now push the free end of the slinky in the downward direction and release it. It is observed that the slinky begins to move up and down (i.e. "to and fro") as shown in figure (b). The disturbance travels from the free end to the fixed end and the parts of the slinky vibrate along the direction of the propagation the disturbance. This wave is known as **longitudinal wave**.



When a longitudinal wave passes through a medium, the medium is divided into the regions of **compressions** (C) and **rarefactions** (R) as shown in figure (b).

COMPRESSION

The part or region of a medium, where the density of the medium is maximum or where the particles of the medium are very close to each other is known as compression. It is denoted by C.

RAREFACTION

The part or region of a medium, where the density of the medium is minimum or where the particles of the medium are far apart from each other is known as rarefaction. It is denoted by R.

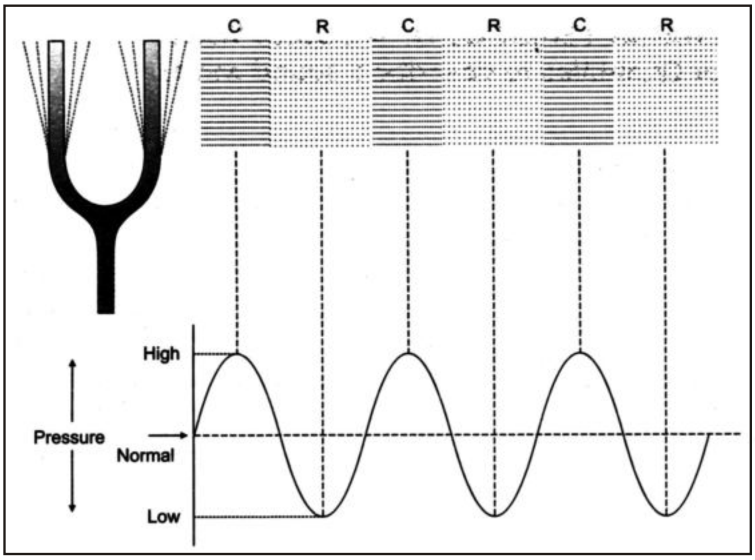
Longitudinal waves	***Transverse waves***
1. In a longitudinal wave the particles of the medium oscillate along the direction of propagation of the wave.	1. In a transverse wave, the particles of the medium oscillate in a direction perpendicular to the direction of propagation of the wave.
2. Longitudinal waves can propagate through solids, liquids, as well as gases.	2. Transverse waves can propagate through solids, and over the surface of liquids, but not through gases.
3. Longitudinal waves consist of compressions and rarefactions.	3. Transverse waves consist of crests and troughs.

PROPAGATION OF SOUND

A vibrating body produces sound. Now we shall study, how the sound travels from one place to another place.

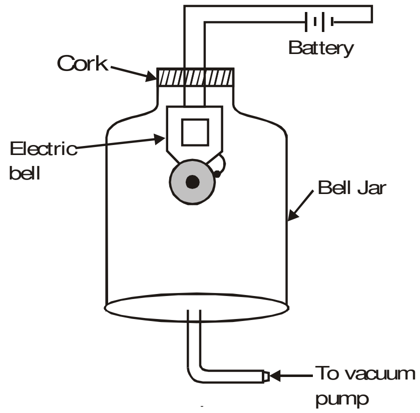
When a body vibrates, then the particles of the medium (say air) around the vibrating body are set into vibrations. The particles of the medium which are very close to the vibrating body are pushed away from the body. These particles of the medium strike against the neighbouring particles. Hence the number of particles of the medium in the region where the displaced particles strike against the neighbouring particles is large. This region is known as compression (C). Since pressure is directly proportional to the number of particles, so the **compression** is a region of **high pressure or high density.** When the vibrating body moves backward, a region of emptiness known as **rarefaction (R)** or a region of **low pressure or Low density** is created. The displaced particles of the medium rebound into the region of low pressure or rarefaction. At the same time, compression is followed outwards. Therefore, when a body vibrates to produce sound, compressions and rarefactions follow one another as the sound waves travel through the' medium away from the vibrating body. When a sound wave travels through a medium, the particles of the medium simply vibrate about their rest positions and they do not move from one place to another place in the medium.

Figure represents the regions of compressions (or high pressures) and o rarefactions (or low pressures) as the sound propagates in the medium.



SOUND NEEDS A MEDIUM TO TRAVEL

We have learnt that sound travels from one place to another place when the energy is transferred from one particle to another particle of a medium like air or gas, liquid, solid etc. It means, sound needs a material medium for its propagation. In other words, sound cannot travel through vacuum.



DEMONSTRATION TO SHOW THAT SOUND WAVES CANNOT TRAVEL THROUGH VACUUM.

Put an electric bell inside a closed Bell jar connected with a vacuum pump. Initially, air from the jar is not taken out. Connect the electric bell with a battery (Figure). It rings and the sound produced is heard by us.

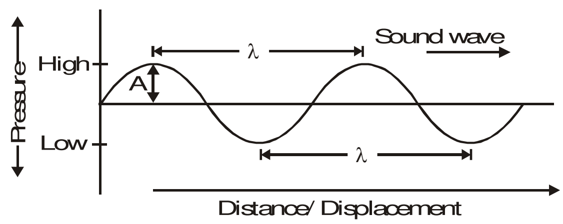
Now start evacuating the air from a Bell jar using a vacuum pump, we will hear less and less sound. i.e. the **loudness** of the sound decreases. When there is no air in the Bell jar, we do not hear sound. This activity demonstrates that sound waves require material medium (in this case air) for its propagation.

SOUND WAVES ARE LONGITUDINAL WAVES

When a sound wave travels through the material medium, then compressions and rarefactions follow one another. The particles of the medium through which a sound wave travels vibrate to and fro about their mean positions parallel to the direction of propagation of the sound wave. Since the wave is known as longitudinal wave, if the particles of the medium vibrate to and fro about their mean positions parallel to the direction of propagation of the wave, therefore, the sound waves are longitudinal waves.

CHARACTERISTICS OF A SOUND WAVE

When a sound wave travels through a material medium, then the density or pressure of the medium changes continuously from maximum value to minimum value and vice-versa. Thus, the sound wave propagating in a medium can be represented as shown in figure.



Now, we shall discuss the characteristics or quantities to describe a sound wave.

(i) **Amplitude :** The maximum displacement of a vibrating body or particle from its rest position (i.e. mean position) is called amplitude.

(ii) Wavelength (or length of a wave) : The distance between two successive 1 regions of high pressure or high density (or compressions) or the distance between two successive regions of low pressure or low density (or rarefactions) is known as wavelength of a sound wave. It is denoted by λ (read as lambda). In S.I., unit of wavelength is metre (m).

(iii) Frequency : The number of oscillations or vibrations made by a vibrating body or particles of a medium in one second is known as the frequency of a wave. It is denoted by υ (read as Neu). In S.I., unit of frequency is hertz (Hz).

1 hertz = one oscillation completed by a vibrating body or a vibrating particle in one second.

(iv) Time period : Time taken by a vibrating particle or a body to complete one vibration or oscillation is known as time period. It is denoted by T.

In S.I., unit of time period is second(s).

Relation between Frequency and time period Let T = time period of a vibrating body.

Then number of oscillations completed in T second = 1

$\therefore$ number of oscillations completed in 1 second = $\frac{1}{T}$

But number of oscillations completed in 1 second = frequency (v)

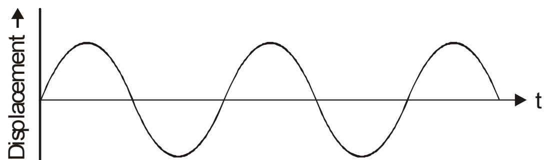
$\therefore$ (f) $\nu = \frac{1}{T}$, frequency = $\frac{1}{\text{Time period}}$

(iv) Pitch or Shrillness : Pitch is the characteristic (i.e., typical feature) of a sound that depends on the frequency received by a human ear.

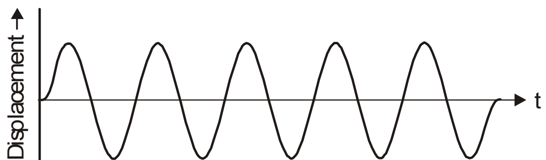
A sound wave of high frequency has high pitch and a sound wave of low frequency has a low pitch.

You must have noticed that the voice of a woman has higher pitch than the voice of a man. Thus, the frequency of woman's voice is higher than the frequency of man's voice.

A sound wave of low pitch (i.e. low frequency) is represented by figure (a) and a sound wave of high pitch (i.e. high frequency) is represented by figure (b)



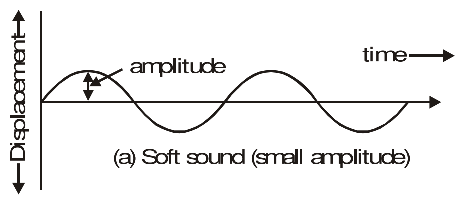
(a) Low frequency sound wave



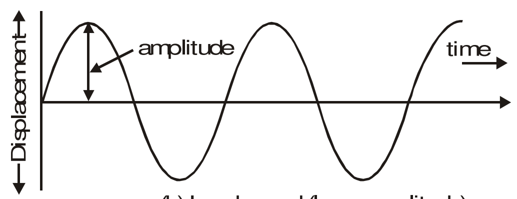
(b) High frequency sound wave

(v) Loudness : Loudness of a sound depends on the amplitude of the vibrating body producing the sound.

A sound produced by a body vibrating with large amplitude is a loud sound. On the other hand, a sound produced by a body vibrating with small amplitude is a feeble or soft sound. Loud sound and soft or feeble sound are represented as shown in Figure (a) and (b) respectively.



(a) Soft sound (small amplitude)



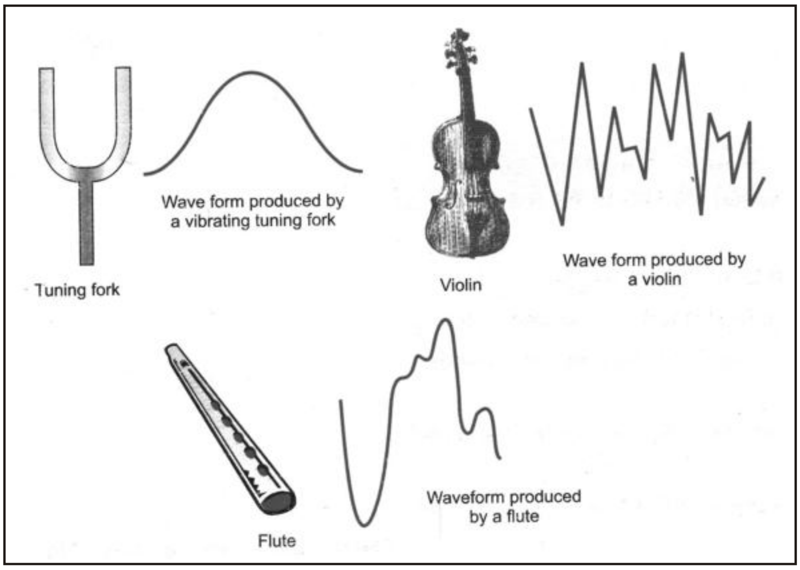
(b) Loud sound (large amplitude)

Loudness is a subjective quantity : It depends on the sensitivity or the response of our ears. A loud sound to a person may be a feeble sound for another person who is hard of hearing.

(vi) **Timbre or quality :** Quality or timbre is a characteristic (i.e., a typical feature) of a sound which enables us to distinguish between the sounds of same loudness and pitch.

This characteristic of sound helps us to recognise our friend from his voice without seeing him.

The quality of two sounds of same loudness and pitch produced by two different sources are distinguishable because of different waveforms produced by them. The waveforms produced by a vibrating tuning fork, violin and flute (Bansuri) are shown in figure.



(vii) **Intensity :** Intensity of a sound is defined as the sound energy transferred per unit time through a unit area placed perpendicular to the direction of the propagation of sound.

That is, intensity of sound = $\frac{\text{Sound energy}}{\text{Time} \times \text{Area}}$

Intensity of a sound is **an objective physical quantity.** It does not depend on the response of our ears.

In S.I., unit of intensity of sound is **joule s^{-1} m^{-2} or watt m^{-2}** **($\because$ $1Js^{-1} = 1W$)**

S.No.	Loudness	Intensity of a sound
1	Loudness is a subjective quantity, it depends upon the sensitivity of the human ear. A sound may be loud for a person but the same sound may be feeble for another who is hard of hearing.	Intensity of a sound is an objective physical quantity. It does not depend on the sensitivity of a human ear.
2	Loudness cannot be measured as a physical quantity because it is just sensation which can be felt only.	Intensity of a sound can be measured as a physical quantity.

RELATIONSHIP BETWEEN WAVE VELOCITY, FREQUENCY, AND WAVELENGTH FOR A PERIODIC WAVE.

What is the relationship between wave velocity, frequency and wavelength

From the definition,

$$\text{Velocity} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

So, for a wave,

$$\text{Wave velocity} = \frac{\text{Distance travelled by the wave}}{\text{Time taken}}$$

A wave takes time equal to its time period (T) to travel a distance equal to its wavelength (λ). So,

$$\text{Wave velocity} = \frac{\text{Wavelength of the wave}}{\text{Time period of the wave}} \qquad ...(1)$$

$$\text{or} \qquad v = \frac{\lambda}{T} \qquad ...(2)$$

As per definition,

$$\text{Frequency of the wave, } \upsilon = \frac{1}{\text{Time period of the wave}} = \frac{1}{T}$$

So, Eq. (2) can be written as,

Wave velocity = Frequency of the wave × Wavelength of the wave

$$\text{or} \qquad \boxed{v = \upsilon \times \lambda}$$

Newton's Thought
How does lightning produce thunder, and what causes the extended rumble? **Explanation** Assume that you're at ground level. When lightning strikes, a channel of Ionized air carries a large electric current from a cloud to the ground. This results in a rapid temperature increase of the air in the channel as the current moves through it, causing a rapid expansion of the air. The expansion is so sudden and so intense that a tremendous disturbance is produced in the air i.e., a thunder. The entire length of the channel produces the sound at the same instant of time. Sound produced at the bottom of the channel reaches you first, because that's the point closest to you. Sound from progressively higher portions of the channel reach you at later times, resulting in an extended roar might be steady, but the zigzag shape of the path results in the rumbling variation in loudness, with different quantities of sound energy from different segments arriving at any given instant.

SPEED OF SOUND IN DIFFERENT MEDIA

We have seen above that sound can travel through **solids, liquids and gases.** The question which comes to mind is how fast does sound travel? Sound travels at different speeds in different media.

The speed of sound depends on the following factors :

- The properties (or nature) of the medium. The order of the speed of sound is

  SOLIDS > LIQUIDS > GASES

- Temperature
- Pressure
- In any medium, the speed of sound is **increases with** a rise in **temperature.**

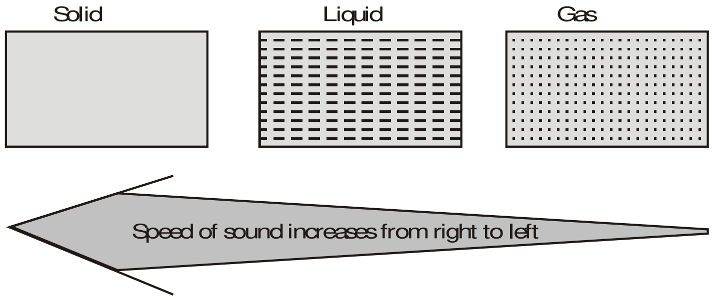
As per definition,

$$\text{Speed of sound} = \frac{\text{Distance travelled by the sound}}{\text{Time taken}}$$

The speed of light in the air (or more correctly in vacuum) is 3×10^8 m/ s, (3lakh kilometre per second).

CONCLUSION

Speed of sound in solids is greater than the speed of sound in liquids and the speed of sound in liquids is greater than the speed of sound in gases.



SPEED OF SOUND IN VARIOUS MEDIA

Gases	
Air (0°C)	331
Air (20°C)	343
Oxygen (0°C)	317
Helium (0°C)	972
Hydrogen (0°C)	1286
Liquids	
Water (25°C)	1493
Sea water (25°C)	1533
Methylalcohol(25°C)	1143
Blood (37°C)	1570
Solids	
Aluminium (20°C)	5100
Copper (20°C)	3560
Iron (20°C)	5130
Vulcanized rubber	54
Glass (20°C)	5170
Granite (20°C)	6000

Newton's Thought

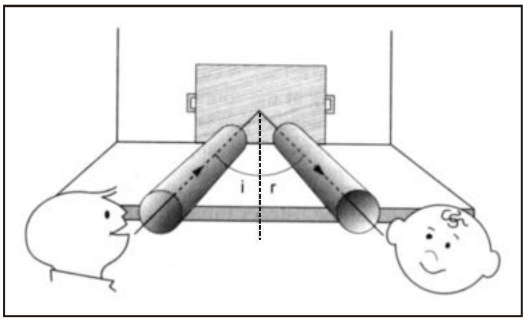
Why speed of sound is fastest in solids and slowest in gases?

Explanation

Speed of sound waves depends on the nature of material (or medium). As a sound wave travels through a material, the particles in the material collide with each other. In a solid, molecules are closer together than in liquids or gases, so collisions between molecules occur more rapidly than in liquids or gases. Thus, the speed of sound is fastest in solids, where molecules are closest together, and slowest in gases, where molecules are farthest apart.

REFLECTION OF SOUND

When a sound wave travelling in a medium bounces back to the same medium after striking the second medium, reflection of sound wave is said to take place. The reflection of sound wave is similar to the bouncing back of a rubber ball after striking a wall or the surface of a floor.



Just like light, sound is reflected by the solid and liquid surfaces. The reflection of sound obeys the laws of reflection.

The laws of reflection of sound are as follows :

(i) Incident angle = Reflected angle and (ii), The incident direction of sound, reflected direction of sound and the normal to the point of incidence all lie in the same plane.

ECHO

If we clap our hands while standing at some distance from a high and huge wall or a hill, we hear the clapping of our hands again after some short interval of time. The sound of clap heard by us is known as echo. Echo is produced due to the reflection of sound.

Thus, echo is a repetition of sound due to the reflection of original sound by a large and hard obstacle.

CONDITIONS FOR THE PRODUCTION OF AN ECHO

1. Time gap between the original sound and the reflected sound

We can hear the two sounds separately if the time gap between these two sounds is more than 1/10 s or 0·1 s. The time interval equal to 0·1 s is known as **persistance of hearing.** This means, the impression of any sound heard by us remains for 0·1 s in our brain. If any other sound enters our ears before 0·1 s, then the second sound will not be heard by us. Thus, the echo will be heard if the original sound reflected by an obstacle reaches our ears after 0·1 s.

2. Distance between the source of sound and obstacle

Minimum distance between the observer and the obstacle for echo to be heard

Let

Distance between the observer and the obstacle = d

Speed of sound (in the medium) = v

Time after which echo is heard = t

Then, $t = \frac{2d}{v}$ or $d = \frac{vt}{2}$

We know

Speed of sound; in air at 25°C = 343 m s^{-1}

For an echo to be heard distinctly,

$t \geq 0.1$ s

Then $d \geq \frac{343ms^{-1} \times 0.1s}{2}$

or $d \geq 17.2$ m

Thus, the minimum distance (in air at 25°C) between the observer and the obstacle for the echo to be heard clearly should be 17.2 m.

The speed of sound increases with a rise in temperature. Therefore, the minimum distance in air between the observer and the obstacle for an echo to be heard clearly at temperatures higher than 25°C is more than 17.2m. In rooms having walls less than 17.2 m away from each other, no echo can be heard.

3. **Nature of the obstacle :** For the formation of an echo, the reflecting surface or the obstacle .must be **rigid** such as a building, hill or a cliff.

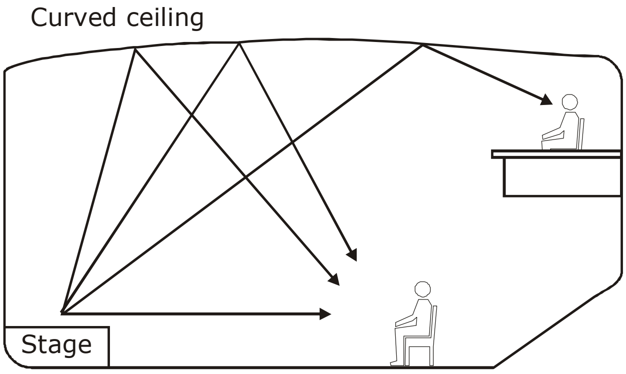
4. **Size of the obstacle :** Echoes can be produced if the size of the obstacle reflecting the sound is **quite large.**

REVERBERATION

The repeated reflection that results in the persistence of sound in a large hall is called reverberation.

Excessive reverberation in any auditorium/hall is not desirable because the sound becomes blurred and distorted. The reverberation can be minimised/reduced by covering the ceiling and walls with sound absorbing materials such as, fiber-board, rough plaster, draperies, perforated cardboard sheets etc.

When a sound is produced in a big hall, its waves reflects from the walls and travel back and forth. Due to this the sound does not vanish at once but it fades away gradually, that is the sound persists even after its production has been stopped. A small amount of reverberation is desirable in large halls or cinemas as it makes the sound pleasant and more effective. How ever too much reverberation is undesirable as it makes the sound confusing. To reduce reverberation the roof and walls of the hall are covered with sound absorbing materials like rough plaster and thick curtains. One may define reverberation as the persistance of sound due to repeated reflection and its gradual fadding away.



Newton's Thought

Do you think reverberation characteristics should be same for an auditorium made for rock concerts and a school's lecture hall?

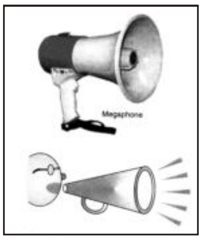
Explanation

No, auditoriums, churches, concert halls, libraries, and music rooms are designed with specific functions in mind. One auditorium may be made for rock concerts, while another is constructed for use as a lecture hall. Your school's auditorium, for instance, may allow you to hear a speaker well but make a band sound damped and muffled.

Rooms are often constructed so that sounds made by a speaker or a musical instrument bounce back and forth against the ceiling, walls, floor, and other surface. This repetitive echo is called reverberation. The reverberation time is the amount of time it takes for a sound's intensity to decrease by 60 dB. For speech, the auditorium should be designed so that the reverberation time is relatively short. A repeated echo of each word could become confusing to listeners. Music halls may differ in construction depending on the type of music usually played there. For example, rock music is generally less pleasing with a large amount of reverberation, but more reverberation is sometimes desired for orchestral and choral music. For these reasons, you may notice a difference in the way ceilings, walls, and furnishings are designed in different rooms.

USES OF MULTIPLE REFLECTION OF SOUND

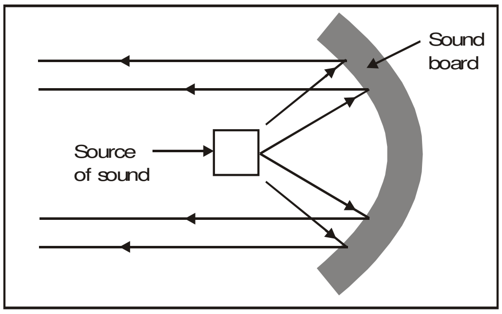
1. **Megaphone :** Megaphone is a device used to address public meetings. It is a horn-shaped. When we speak through megaphone, sound waves are reflected by the megaphone. These reflected sound waves are directed towards the people (or audience) without much spreading.



2. **Hearing Aid :** Hearing aid is used by a person who is hard of hearing. The sound waves falling on hearing aid are concentrated into a narrow beam of sound waves by reflection. This narrow beam of sound waves is made to fall on the **diaphragm** of the ear. Thus, diaphragm of the ear vibrates with large amplitude. Hence, the hearing power of the person is improved.

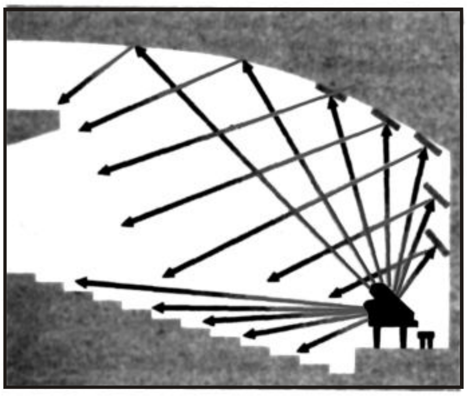
3. **Sound boards :** Sound boards are curved surfaces (concave) which are used in a big hall to direct the sound waves towards the people sitting in a hall. The speaker is (i.e. source of sound) placed at the focus of the sound board as shown in figure.

   Sound waves from the speaker are reflected by die sound board and these reflected waves are directed towards the people (or audience).



4. **Stethoscope :** Stethoscope is a device used by doctors to listen the sound produced by heart and lungs. The sound produced by heart beat and lungs of a patient reaches the ears of a doctor **due to multiple reflection** of sound.

5. **Ceilings of concert halls are curved :** The ceilings of concert halls and auditoriums are made curved. This is done so that the sound reaches all the parts of the hall after reflecting from the ceiling as shown in figure. Moreover, these ceilings are made up of sound absorbing materials to reduce the reverberation.



RANGE OF HEARING (AUDIBLE RANGE)

All vibrating bodies produce waves. Each wave has its own frequency. The frequency of a wave is equal to the frequency of the vibrating body producing sound. When a woman speaks, the waves produced by the vocal cords in her throat have different frequency than the frequency of the waves produced by the vocal cords of a man. Can human ears hear all the frequencies produced by the vibrating bodies ? The answer is No. In fact, normal human ears can hear only those waves whose frequency lies between 20 Hz and 20,000 Hz. The waves having frequency between 20 Hz and 20,000 Hz are known as sound waves. Thus, the audible range of frequency is 20 Hz to 20,000 Hz.

The waves having frequency less than 20 Hz and greater than 20,000 Hz cannot be heard by human ear.

INFRASONICS OR INFRASOUND

The waves of frequency **less than 20 Hz** are known as infrasonic waves.

The infrasonic waves are produced by large vibrating bodies.

For example, infrasonic waves are produced by the vibration of the earth's surface during the earthquake. Some animals like elephants, rhinoseroses and whales etc. also produce infrasonic waves. These waves are not audible to a human ear.

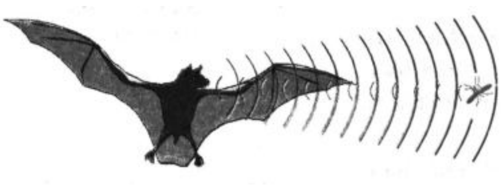
It has been observed that animals behaviour becomes unusual just before the tremor is felt. This is because the animals has the ability to detect infrasonic waves produced at the time of tremor.

ULTRASONICS OR ULTRASOUND

The waves of frequency **greater than 20,000 Hz** are known as ultrasonic waves or ultrasound. These waves are not audible to a human ear but they can be heard by animals and birds.

Bats can produce ultrasonic waves by flapping their wings. They can also detect these waves. The ultrasonic waves produced by the bats after reflection from the obstacles like buildings guide them to remain away from the obstacles during their flights. Hence, they can fly during night without hitting the obstacles. Bats also catch their **prey** during night with the help of ultrasonic waves. The ultrasonic waves produced by a bat spread out. These waves after reflecting from a prey sayan insect reach the bat. Hence, the bat can easily locate its prey.

Dolphins also produce ultrasonic waves. They can also detect the ultrasonic waves. They catch their prey like a fish due to their ability to detect the ultrasonic waves reaching them after reflecting from a fish.



APPLICATIONS OF ULTRASOUND (ULTRASONIC WAVES)

Ultrasonic waves have number of uses :

1. Ultrasonic vibrations are used for **homogenising milk,** i.e., the milk is agitated with ultrasonic vibrators. These vibrations break down the larger particles of the fat present in milk to smaller particles.

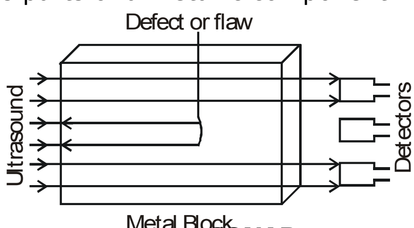
2. Ultrasonic vibrations are used in **dish washing machines.** In such machines, water and detergent are vibrated with ultrasonic vibrators. The vibrating detergent particles rub against the **dirty utensils** and thus clean them.

3. Ultrasonic vibrations produce a **sort of depression in rats and cockroaches.** Ultrasonic vibrators are used to drive rats and cockroaches from godowns.

4. Ultrasonic vibrations are used for imaging internal organs of human body. In fact they are even used to study the growth of foetus in mother's womb.

5. Ultrasonic vibrations are used in relieving pain in joints and muscles.

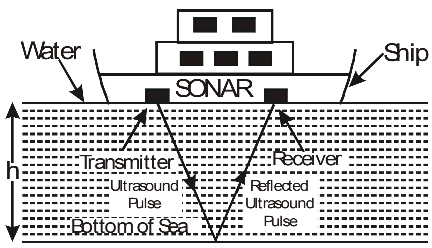
6. Ultrasonic vibrations are used in detecting flaws in articles made from metals. They are also used in finding the thickness of various parts of a metallic component.



SONAR

SONAR stands for Sound Navigation and Ranging.

It is a device which is used in the ships to locate rocks, icebergs, submarines, old ships sank in sea ete. It is also used to measure the depth of a sea.



PRINCIPLE : It is based on the principle of the **reflection of sound wave** (i.e. echo).

Determination of the Depth of a Sea using Sonar

A beam of ultrasonic waves from the **transmitter of a SONAR** fitted on the ship is sent towards the bottom of the sea. This beam is reflected back from the bottom of the sea and is **received by the receiver** of the SONAR on the ship.

The time taken by the ultrasonic waves to go from the ship to the bottom of the sea and then back to the ship is noted. Let it be 't' seconds. Therefore, the time taken by the ultrasonic waves to go from the ship to the bottom of the sea is $\left(\frac{t}{2}\right)$ seconds.

Using the following formula $S = v\left(\frac{t}{2}\right)$. we can find the depth of the sea.

Here, u = speed of ultrasonic wave in water.

S = depth of the sea

THE HUMAN EAR

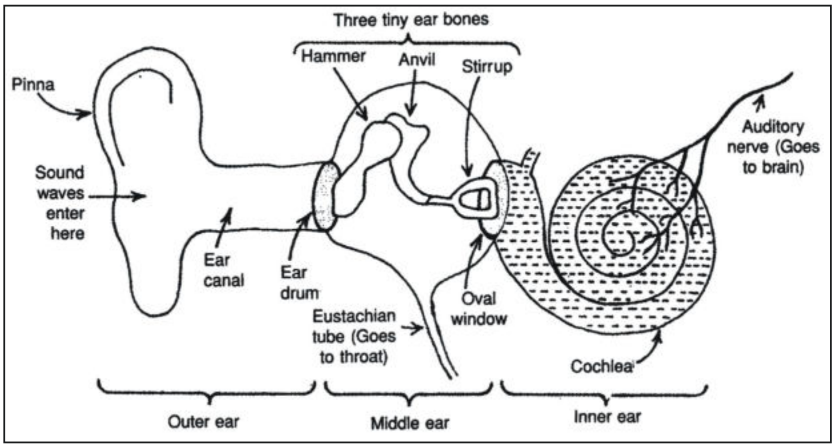
In this article we will learn about the accoustics of hearing. We will see how a human ear converts sound energy into mechanical energy and then to a nerve impulse which is transmitted to the brain.

The human ear consists of (a) the outer ear (pinna), (b) the middle ear, (c) the inner ear. Each part has a specific task to perform. The outer ear, collects the sound and guides it to the middle ear. In the middle ear sound energy is converted into mechanical energy in the form of internal vibrations of the bone structure. These vibrations are then transferred into the inner ear which converts the vibrations into nerve impulses.

The outer ear has an approximately 2 cm tong ear canal. Here the sound is collected and amplified. It is in the form of pressure waves with alternate high pressure and low pressure regions.

The middle ear consists of eardrum (tympanic membrane) three tiny inter connected bones-the hammer (mallens), anvil (incus) and stirrup (stapes). The eardrum is a tightly stretched membrane. As the incoming pressure wave from the outer ear strikes, the ear drum starts to vibrate. A compression forces the eardrum inwards whereas a rarefaction forces the eardrum outwards. This means that the eardrum vibrates at the same frequency as that of the sound wave. The eardrum is connected to hammer which in turn is connected to anvil and stirrup. The motion of eardrum will set the hammer, anvil and stirrup into motion at the same frequency as that of eardrum. The three-bone system amplifies the sound further.

The stirrup is connected to the inner ear which consists of cochlea, semi circular canals and the auditory nerve. The vibrations are turned into electrical signals in inner ear which are sent to the brain via the auditory nerve. The brain interprets the sound by the electrical impulses it receives.



Some suggestions to keeps the ears healthy are given below:

Never insert any pointed object into the ear. It can damage the eardrum and make a person deaf.

Never shout loudly or produce a loud sound into someone's ear.

Never hit anyone hard on his/her ear.

SOLVED PROBLEMS

Ex.1 A source of wave produces 40 crests and 40 troughs in 0.4 second. Find the frequency of the wave.

Sol. Number of crests and troughs produced by the wave = 40

Number of waves formed = 40

Time taken = 0.4 s

Frequency = ?

Number of waves produced in one second = $\frac{40}{0.4s} = 100\ s^{-1}$

Frequency of the wave = 100 Hz

Ex.2 A person has a hearing range from 20 Hz to 20 kHz. What are the typical wavelengths of sound waves in air corresponding to these two frequencies? Take the speed of sound in air as 344 m s^{-1}.

Sol. Hearing range = 20 Hz to 20 kHz (= 20000 Hz)

Speed of sound in the air = 344 m s^{-1}

For a wave,

$$\text{Wavelength} = \frac{\text{Wave velocity}}{\text{Frequency}}$$

or $\lambda = \frac{v}{\nu}$

So, for v = 20Hz = 20 /s

$$\lambda = \frac{344ms^{-1}}{20s^{-1}} = 17.2m$$

and for v = 20000 Hz = 20000 s^{-1}

$$\lambda = \frac{344ms^{-1}}{20000s^{-1}} = 0.0172m = 1.72\ cm$$

Ex.3 Calculate the wavelength of a sound wave whose frequency is 220 Hz and speed is 440 m/ s in a given medium.

Sol. Frequency, v = 220 Hz

Speed of sound, v = 440 m/ s

The wavelength can be described by the relationship,

Wave velocity = Wavelength of the wave x Frequency of the wave

440 m s^{-1} = $\lambda \times 220$ Hz = $\lambda \times 220\ s^{-1}$

So $\lambda = \frac{440ms^{-1}}{220s^{-1}} = 2$ m

Therefore, wavelength of the sound wave is 2 m.

Ex.4 A person is listening to sound of 50 Hz sitting at a distance of 450 m from the source of sound. What is the time interval between successive compressions from the source reaches him?

Sol. Frequency of the sound = 50 Hz

Distance from the source = 450 m

Time between the successive compressions is equal to time taken by the sound to travel a distance equal to its wavelength. Thus, we have to find out the time period we know,

Time period, $T = \dfrac{1}{\text{Frequency } (v)}$

So $T = \dfrac{1}{50\text{Hz}} = \dfrac{1}{50\text{s}^{-1}} = 0.02$ s

The successive compressions will reach the person after every 0.02 s.

Ex.5 A human heart, on an average, is found to beat 75 times a minute. Calculate its frequency.

Sol. No. of beats of human heart = 75 min^{-1} = $\dfrac{75}{1\text{min}} = \dfrac{75}{60\text{s}}$ = 1.25 s^{-1}

So, Average frequency of human heart beating = 1.25 s^{-1}

Ex.6 A boat at anchor is rocked by waves whose consecutive crests are 100 m apart. The wave velocity of the moving crests is 20 m/ s. What is the frequency of rocking of the boat?

Sol. Distance between two consecutive crests = 100 m

Wave velocity v = 20 m/ s

The distance between two consecutive crests is equal to the wavelength of the wave. So,

Frequency = $\dfrac{\text{Wave velocity}}{\text{Wave length}} = \dfrac{20\text{m/s}}{100\text{m}}$ = 0.2 s^{-1}

So, the frequency of rocking of the boat is 0.2 s^{-1}.

Ex.7 A longitudinal wave is produced on a toy slinky. The wave travels at a speed of 30 cm/ s and the frequency of the wave is 20 Hz. What is the minimum separation between the consecutive compressions of the slinky?

Sol. Wave speed, v = 30 cm/ s

Frequency of the wave, v = 20 Hz = 20 s^{-1}

The minimum separation between the consecutive compressions is equal to the wavelength. Therefore,

Wavelength = $\dfrac{\text{Wave speed}}{\text{Frequency}} = \dfrac{30\text{cm/s}}{20\text{s}^{-1}}$ = 1.5 cm

Thus, the minimum separation between the consecutive compression of the slinky is 1.5 cm.

Ex.8 A bat can hear sound at frequencies up to 120 kHz. Determine the wavelength of sound in the air at this frequency. Take the speed of sound in the air as 344 m/s.

Sol. Frequency, v = 120 kHz = 120 × 10^3 Hz = 120 × 10^3 s^{-1}

Velocity of sound in the air, v = 344 m/s

Wavelength of the sound wave, λ = ?

We know,

Wavelength, $\lambda = \dfrac{\text{Wavevelocity}}{\text{Frequency}} = \dfrac{344\text{m/s}}{120\times10^3\text{s}^{-1}}$

= 2.87 × 10^{-3} m = 0.29 cm

Ex.9 A gun is fired in the air at a distance of 660 m, from a person. He hears the sound of the gun after 2 s. What is the speed of sound?

Sol. Distance travelled by sound = 660 m, Time taken by the sound = 2 s, Speed of sound in air = ?

So, Speed of sound = $\frac{\text{Distance travelled by sound}}{\text{Time taken by the sound}}$

Speed of sound = $\frac{660\text{m}}{2\text{s}}$ = 330 m/s

Thus, the speed of sound in the air is 330 m/s.

Ex.10 A child hears an echo from a cliff 4 seconds after the sound from a powerful cracker is produced. How far away is the cliff from the child? Velocity of sound in air at 20°C is 344 m/ s.

Sol. Let the distance between the child and the cliff be d. Then,

Total distance travelled by the sound = 2d

Total time taken by the sound = 4 s

Then,

Velocity of sound = $\frac{2d}{4s} = \frac{d}{2s}$

344 m/s = $\frac{d}{2s}$

This gives, d = 344 m/s × 2s = 688 m

Thus, the cliff is at a distance of 688 m from the child.

Ex.11 A ship sends on a high frequency sound wave and receives an echo after 1 second. What is the depth of the sea? Speed of sound in water is 1500 m/ s.

Sol. Let,

Depth of the sea = d

So, Total distance travelled by the sound wave = 2d

Time taken by sound to travel both ways = 1 s

As per definition,

Speed of the sound = $\frac{\text{Total distance travelled}}{\text{Time taken}}$

Then, 1500 m s^{-1} = $\frac{2d}{1s}$

or d = $\frac{1500\text{ms}^{-1} \times 1\text{s}}{2}$ = 750 m

Thus the depth of the sea is 750 metres.

Ex.12 A sonar echo takes 2.2 s to return from a whale. How far away is the whale?

Sol. Total time taken by the signal = 2.2 s

So, Time taken the signal to reach the whale = $\frac{2.2\text{s}}{2}$ = 1.1 s

Distance of the whale = d ?

From the literature, speed of sound in sea water at 25°C = 1533 m s^{-1}

So, Distance of the whale, d = Speed of the signal x Time taken

or d = 1533 m s^{-1} × 1.1 s = 1686.3 m

Ex.13 Using the SONAR, sound pulses are emitted at the surface of water. These pulses after being reflected from the bottom are detected. If the time interval from the emission to the detection of the sound pulses is 2 seconds, find the depth of the water. Velocity of sound in water = 1498 m/s.

Sol. Let, depth of the water from the earth's surface be d. Then,

Total distance travelled by the pulse = 2d

Total time taken by the pulse = 2 s

As per definition,

$$\text{Velocity} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

$$\text{So, Velocity of the sound} = \frac{2d}{2s} = \frac{d}{1s}$$

$$1498 \text{ m/s} = \frac{d}{1s}$$

This gives,

$$d = 1498 \text{ m/s} \times 1s = 1498 \text{ m}$$

Thus, the depth of water is 1498 m.

Ex.14 A wave moves a distance of 8 m in 0.05 s.

(a) Find the velocity of the wave.

(b) What is the wavelength of the wave if its frequency is 200 Hz ?

Sol. (a) $\text{Velocity} = \frac{\text{Distance}}{\text{Time}} = \frac{8}{0.05} = 160 \text{ ms}^{-1}$

(b) $v = \upsilon\lambda \qquad \therefore \qquad \lambda = \frac{v}{\upsilon} = \frac{160}{200} = 0.8\text{m}$

Ex.15 Two children are at opposite ends of an iron pipe. One strikes his end of the iron pipe with a stone. Find the ratio of times taken by the sound waves in air and in iron to reach the other child. Given velocity of sound in air is 344 ms^{-1} and that in iron is 5130 ms^{-1}.

Sol. For air $v_a = \frac{x}{T_a}$ ...(1)

where v_a is velocity of sound in air.

and T_a is the time taken for the sound to travel in air through the length of pipe x.

For pipe $v_p = \frac{x}{T_p}$ ...(2)

where v_p is the velocity of sound in iron pipe.

T_p is the time taken for the sound to travel in iron pipe through the length of the pipe x. On dividing (1) and (2),

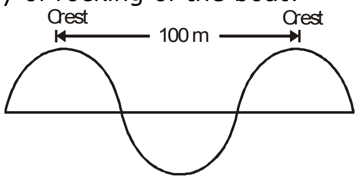
$$\frac{v_a}{v_p} = \frac{x/T_a}{x/T_p} = \frac{T_p}{T_a}$$

$$\frac{T_a}{T_p} = \frac{5130}{344} = 14.9$$

In other words, according to the example, sound travels 14.9 times faster through iron than through air.

Ex.16 A boat at anchor is rocked by waves whose consecutive crests are 100 m apart. The wave velocity of the moving crests is 20 m/s. What is the frequency of rocking of the boat?

Sol. Given λ = 100 m, v = 20 m/s

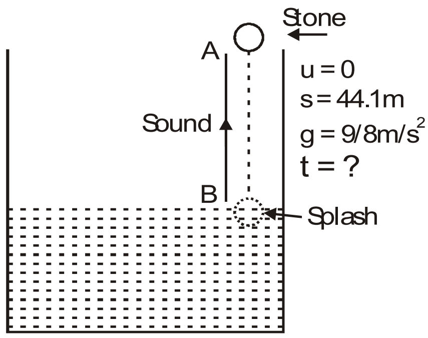


Now $\quad v = \nu\lambda$.

$$\nu = \frac{v}{\lambda} = \frac{20}{100} = 0.2 \text{ Hz}$$

Ex.17 A stone is dropped into a well 44.1 m deep. The splash is heard 3.13 seconds after the stone is dropped. Find the velocity of sound in air.

Sol. Stone falling from A to B



u = 0, S = 44.1 m, g = 9.8 ms^{-2}, t = ?

$$s = ut + \frac{1}{2}gt^2$$

$$44.1 = \frac{1}{2} \times 9.8 \times t^2$$

$\therefore \quad t = 3$ s

Sound produced at B, due to sound produced by the stone falling on the surface of water, travels from B to A. The sound moves with constant velocity.

$$\text{Speed} = \frac{\text{distance}}{\text{Time}}$$

$$v = \frac{44.1}{t'}$$

$$t' = \frac{44.1}{v}$$

It is given that the total time is 3.13 second.

i.e. $t + t' = 3.13$

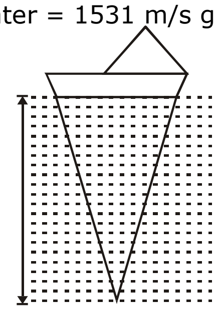
$$\therefore \quad 3 + \frac{44.1}{v} = 3.13$$

$$\Rightarrow \quad \frac{44.1}{v} = 0.13$$

$$\Rightarrow \quad v = \frac{44.1}{0.13} = 339.2 \text{ ms}^{-1}$$

Ex.18 Using sonar, sound pulses are emitted at the surface of water. These pulses after being reflected from water bottom are detected. If the time interval from the emission to the detection of the sound pulses is 2 seconds, find the depth of the water. [speed of sound in water = 1531 m/s given].

Sol. t = 2 s



$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

$$1531 = \frac{2x}{2}$$

x = 1531 m.

Ex.19 A gun is fired at a distance. Why is the sound heard after the flash is seen?

Ans. The velocity of sound in air is 344 m/ s, whereas the velocity of light is 3×10^8 m/ s. So, light waves travel much faster than the sound waves. As a result, the sound due to gun fire is heard after the flash is seen.

It is due to this reason that during a thunder storm, one sees the lightning much before one hears the thunder (sound).

Ex.20 Which of the following is carried by the waves from one place to another?

(a) mass (b) velocity

(c) wavelength (d) energy

Ans. The correct answer is (d).

Ex.21 At the surface of the moon, there is no atmosphere. Suppose you and your friend land on the moon. Would you and your friend be able to talk to each other? Why?

Ans. No. People cannot talk, on the moon. This is because there is no atmosphere (or medium) on the moon, and the sound needs a medium to travel.

Ex.22 Sound waves are

(a) longitudinal

(b) transverse

(c) partly longitudinal and partly transverse

(d) sometimes longitudinal, sometimes transverse

Ans. Sound waves are longitudinal waves. So, answer (a) is correct.

Ex.23 State two properties of the medium required for wave propagation.

Ans. Any medium required for wave propagation should have the following characteristics.

(i) It should be a material medium.

(ii) The medium should be elastic.

Ex.24 Why are sound waves longitudinal in nature?

Ans. The sound wave is longitudinal because it propagates in any material medium as a series of compressions and rarefactions.

During the propagation of a sound wave, the particles of the medium oscillate back and forth about their mean position in the direction of sound propagation.

SOUND

VERY SHORT ANSWER TYPE QUESTIONS

Q.1 What is sound ?

Ans. Sound is a form of energy which produces the sensation of hearing in our ears.

Q.2 What does wave transfer ?

Ans. Wave transfers energy.

Q.3 What is a mechanical wave ?

Ans. A waves that are characterised by the motion of particles of a medium are called mechanical waves. These waves require material medium for their propagation.

Q.4 What is a traverse wave ?

Ans. If the particles of the medium vibrate about their mean positions at right angles to the direction of propagation of the disturbance, then the wave is called transverse wave..

Q.5 What is a longitudinal wave ?

Ans. If the particles of a medium vibrate or oscillate to and fro about their mean positions along the direction of propagation of the disturbance, then the wave is called longitudinal wave.

Q.6 How a sound is produced ?

Ans. Vibrating bodies produce sound.

Q.7 What do you understand by the terms "compression" and "rarefaction" ?

Ans. A region of high pressure of a medium when wave travels through it is called compression. A region of low pressure of a medium when wave travels through it is called rarefaction.

Q.8 What happens to the medium through which sound travels ?

Ans. A medium is divided into the regions of high pressure or high density and regions of low pressure or low density called compressions and rarefactions respectively.

Q.9 What do you understand by the wavelength of a sound wave ?

Ans. Distance between two successive compressions or successive rarefactions is called wavelength of a sound wave.

Q.10 What do you understand by the frequency of a sound wave ?

Ans. The number of vibrations or oscillations made by a vibrating body in one second is called the frequency of a sound wave.

Q.11 Name the physical quantity which determines the pitch of a sound.

Ans. Frequency of a sound wave.

Q.12 Name the physical quantity which determines the loudness of a sound.

Ans. Amplitude of the vibrating body.

Q.13 What do you understand by the pitch of a sound ?

Ans. Pitch of a sound is the characteristic of sound that depends on the frequency received by a human ear.

Q.14 What do you understand by the loudness of a sound ?

Ans. Amplitude of the vibrating body determines the loudness of the sound. Large is the amplitude of vibration, large is the loudness of the sound produced.

Q.15 Define the characteristic "timbre" or "quality" of a sound.

Ans. Quality or timber is a characteristic of a sound which enables us to distinguish between two sounds of some loudness and pitch.

Q.16 Which characteristic of a sound helps you to identify your friend by his voice while sitting with others in a dark room ?

Ans. Timbre or quality of sound.

Q.17 What do you mean by the intensity of sound ?

Ans. Sound energy per unit time per unit area is known as the intensity of sound.

Q.18 Write the S.I. unit of intensity of sound.

Ans. $Js^{-1}\ m^{-2}$ or Wm^{-2} (Watt m^{-2}).

Q.19 Out of which of the following media, the speed of sound is maximum : solid, liquid, gas.

Ans. The speed of sound is maximum in solid medium.

Q.20 Sound travels faster as the temperature of the medium increases. Why ?
Ans. Speed of sound increases with increase in temperature.
Q.21 By what amount, the speed of sound in air increases with 1°C rise in temperature of the air?
Ans. 0.61 ms^{-1} or 61 cm s^{-1}
Q.22 What do you understand 'by supersonic speed
Ans. The speed of an object moving faster than the speed of sound is known as supersonic speed.
Q.23 What is a shock wave ?
Ans. The sound waves produced by an object moving with a speed greater than the speed of sound are known as shock waves.
Q.24 What do you understand by Sonic boom ?
Ans. A loud sound produced by shock waves is known as sonic boom.
Q.25 What do you understand by the reflection of sound ?
Ans. The bouncing back of a sound wave after striking a solid surface is called reflection of sound.
Q.26 What is an echo ?
Ans. Echo is a repetition of sound due to the reflection of original sound by a large and hard obstacle.
Q.27 What should be the minimum distance between the source of sound and the obstacle to hear an echo ?
Ans. 17 metres.
Q.28 What do you understand by the reverberation ?
Ans. The phenomenon of prolongation of original sound due to the multiple reflection of sound waves even after the source of sound stops producing sound is called reverberation.
Q.29 What is reverberation time
Ans. The time interval during which original sound appears to prolong.
Q.30 What is the audible range ?
Ans. Audible range is 20 Hz to 20,000 Hz.
Q.31 What are infrasonic waves ?
Ans. The waves of frequency less than 20 Hz are called infrasonic waves.
Q.32 What are ultrasonic waves ?
Ans. The waves of frequency greater than 20,000 Hz are called ultrasonic waves.
Q.33 What type of waves are produced by bats
Ans. Ultrasonic waves.
Q.34 What does SONAR stand for ?
Ans. SONAR stands for Sound Navigation And Ranging.
Q.35 What is the basic principle which SONAR works ?
Ans. SONAR works on the principle of reflection of waves (i.e. echo).

UNDERSTANDING BASED QUESTIONS

Q.1 Explain why echoes can't be heard in a small room.
Ans. For hearing echo, there should be at least a distance of 17 m between the source of sound and the body from which sound is reflected. In small rooms this is not the case, hence echoes are not heard.
Q.2 Why can we hear echoes in long galleries and big halls?
Ans. For hearing echo, there should be at least a distance of 17 m between the source of sound and the body from which sound is reflected. In big rooms and galleries this is so, hence echoes are not heard.
Q.3 Two astronauts cannot hear each other on the moon. Why?
Ans. Material medium is necessary for the propagation of sound. On the moon there is vacuum i.e., no air, therefore, sound cannot propagate on the moon. Thus the astronauts cannot hear each other.
Q.4 Explain why there is usually a time delay between observing a flash and hearing a thunder.
Ans. This is because velocity of light is much greater than the velocity of sound.

Q.5 Bats have no eyes still they can ascertain distances, directions nature and size of the objects. Explain why.

Ans. Bats, have special types of wings. When they fly they produce ultrasonic waves. These waves are received by the ears of bat after they have been reflected by the object. The ears of the bat are so sensitive and trained that they not only get information of distance of the obstacle but also that of the nature of the reflecting surface.

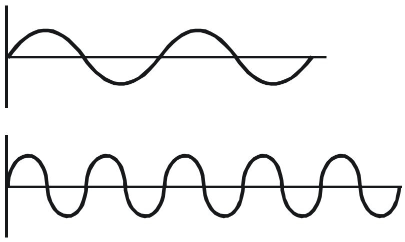
Q.6 Sound is produced due to a vibratory motion, then why a vibrating pendulum does not produce sound?

Ans. The frequency of the vibrating pendulum does not lie within the audible range (20 Hz to 20,000 Hz) and hence it does not produce audible sound.

Q.7 A loud sound can be heard at a large distance but a feeble or soft sound cannot be heard at a large distance. Explain why.

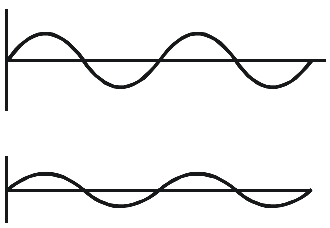
Ans. Sound is a form of energy which is transferred from one place to another. Sound energy is directly proportional to the square of the amplitude of the vibrating body, louder the sound; larger is its energy. As the sound travels through a medium, sound with small energy is absorbed after travelling a small distance in the medium but sound with large energy will be absorbed after travelling a large distance in the medium. Therefore, loud sound can he heard at a large distance but feeble sound cannot be heard at a large distance.

Q.8 Two sound waves A and B are shown in the figure. Identify the sound wave-having
(i) high frequency (ii) low frequency.



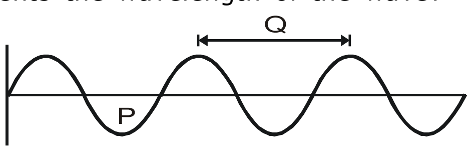
Ans. (i) Wave B has high frequency as it repeats itself after smaller intervals of time.
(ii) Wave A has low frequency as it repeats itself after longer intervals of time.

Q.9 Two sound waves A and B are shown in figure. Identify the sound wave having (i) small amplitude (ii) large amplitude.



Ans. (i) Sound wave B has small amplitude. (ii) Sound wave A has large amplitude.

Q.10 A sound wave travelling in a medium is represented as shown in figure.
(i) Which letter represents the amplitude of the sound wave?
(ii) Which letter represents the wavelength of the wave?



Ans.
(i) Letter P represents the amplitude of the sound wave.
(ii) Letter Q represents the wavelength of the sound wave.

NCERT QUESTIONS WITH SOLUTIONS

Q.1 How does the sound produced by a vibrating object in a medium reach your ear ?

OR

Explain how sound is produced by your school bell.

Ans. Air is the commonest material through which sound propagates. When a vibrating object, like prongs of tuning fork move forward, they push the molecules of the air infront of them. This is turn compresses the air, thus creating a region of high pressure and high density called compression. This compression in the air travels forward. When the prongs of the tuning fork move backward, they create a region of low pressure in the air, commonly called rarefaction. This region has low pressure low density and more volume. As the tuning fork continues to vibrate, the regions of compression in the air alternate with the regions of rarefaction. These regions alternate at the same place. The energy of vibrating tuning fork travels outward. This energy which reaches the ears, makes the ear drums to vibrate and thus we hear sound.

Q.2 A sonar device on a submarine sends out a signal and receives an echo 5 s later. Calculate the speed of sound in water if the distance of the object from the submarine is 3625 m.

Ans. Speed of sound = $\frac{2 \times \text{distance}}{\text{time}} = \frac{2 \times 3625}{5} = 1450\ \text{ms}^{-1}$

Q.3 Why are sound waves called mechanical waves ?

Ans. Some mechanical energy is required to make an object vibrate. Sound energy cannot be produced on its own. the mechanical energy of vibrating object travels through a medium and finally reaches the ear. Therefore, the sound waves are called mechanical waves.

Q.4 Suppose you and your friend are on the moon. Will you be able to hear any sound produced by your friend?

Ans. No, I will not be able to hear sound, because Moon has no atmosphere. Therefore, no sound waves can travel to your ears and therefore, no sound is heard.

Q.5 Which wave property determines

(a) loudness, (b) pitch ?

Ans. (a) The amplitude of the wave determines the loudness; more the amplitude of a wave, more is-the loudness produced.

(b) The pitch is determined by the frequency of the wave. Higher the frequency of a wave, more is its pitch and shriller is the sound.

Q.6 Guess which sound has a higher pitch; guitar or car horn ?

Ans. Car horn has a higher pitch than a guitar, because sound produced by the former is shriller than the later.

Q.7 What are wavelength, frequency, time period and amplitude of a sound wave ?

Ans. **Wavelength :** It is the linear distance between two consecutive compressions or two consecutive rarefactions.

Frequency : The number of compressions or rarefactions taken together passing through a point in-one second is called frequency.

Time Period : It is the time taken by two consecutive compressions or rarefactions to cross a point.

Amplitude : It is the magnitude of maximum displacement of a vibrating particle about its mean position.

Q.8 How are the wavelength and frequency of a sound wave related to its speed ?

Ans. Speed of sound = Frequency × Wavelength

Q.9 Calculate the wavelength of a sound wave whose frequency is 220 Hz and speed is 440 ms^{-1} in a given medium.

Ans. Frequency = 220 Hz

Speed of sound 440 ms^{-1}

We know speed of sound = Frequency × wavelength

$$\Rightarrow \quad \text{Wavelength} = \frac{440}{220} = 2\text{m}$$

Q.10 A person is listening to a tone of 500 Hz sitting at a distance of 450 m from the source of the sound. What is the time interval between successive compressions from the source ?

Ans. Time interval $= \frac{1}{\text{Frequency}} = \frac{1}{500} = 2 \times 10^{-3}\text{s}$

Q.11 Distinguish between loudness and intensity of sound.

Ans. The loudness depends on energy per unit area of the wave and on the response of the ear but intensity depends only on the energy per unit area of the wave and is independent of the response of the ear.

Q.12 In which of the three media, air, water or iron, does sound travel the fastest at a particular temperature?

Ans. Sound travels fastest in iron as compared to water and air.

Q.13 An echo is returned in 3s. What is the distance of the reflecting surface from the source, given that the speed of sound is 342 ms^{-1} ?

Ans. Distance of reflecting body from the source of sound $= \frac{\text{Speed of sound} \times \text{time}}{2} = \frac{342 \times 3}{2} = 513\,\text{m}$

Q.14 Why are the ceiling of concert halls curved ?

Ans. The ceilings of concert halls are curved because sound after reflection from it reaches all the corners of the hall and is audible to each person in the hall.

Q.15 What is the audible range of the average human ear ?

Ans. An average human ear can hear sound waves between frequencies 20 Hz to 20,000 Hz.

Q.16 What is the range of frequencies associated with

(a) Infrasound ? (b) Ultrasound ?

Ans. (a) **Infrasound :** Sound waves between the frequencies 1 to 20-Hz-

(b) **Ultrasound :** Sound waves of the frequencies above 20,000 Hz.

Q.17 A submarine emits a sonar pulse, which returns from an underwater cliff in 1.02 s. If the speed of, sound in salt water is 1531 ms^{-1}, how far away is the cliff ?

Ans. Distance of cliff $= \frac{\text{Speed of sound} \times \text{time}}{2} = \frac{1531 \times 1.02}{2} = 780.81\,\text{m}$

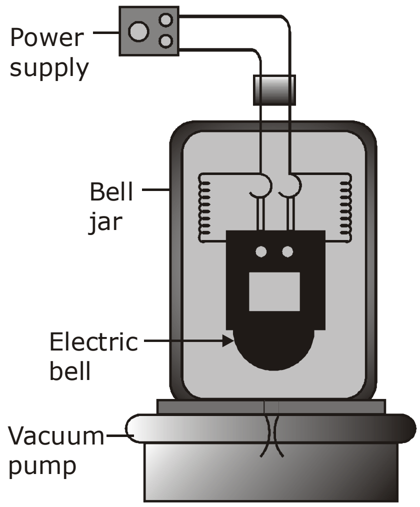
Q.18 What is sound and how is it produced ?

Ans. Sound is mechanical energy which produces sensation of hearing. When an object is set into vibrations, sound is produced.

Q.19 Give an experiment to show that sound needs a material medium for its Propagation.

Ans. Take an electric circuit which consists of a cell, a switch and an electric bell arranged inside a bell jar, which stands on the plat form of an evacuating pump.

The switch of the bell is pressed to close the electric circuit. When there is air within the bell jar, sound is heard. Air is now pumped out of the bell jar. When the air is completely removed from the bell jar, no sound is heard as it is obvious from fig. because the medium of air which has to carry energy from the bell to the bell jar, is removed. It shows that sound needs material medium for its propagation.



Q.20 Why is sound wave called a longitudinal wave ?

Ans. Sound wave is called longitudinal wave because the particles of the medium vibrate in the direction of the propagation of wave.

Q.21 Which characteristic of the sound helps you to identify your friend by his voice while sitting with Miens in a dark room ?

Ans. The characteristic of sound is quality or timbre.

Q.22 Flash and thunder are produced simultaneously. But thunder is heard a few seconds after the flash is seen, why ?

Ans. The speed of light is 3×10^8 ms^{-1} and the speed of sound is 344 ms^{-1} in air. Thus, flash of lightning is seen at first, but sound takes few seconds to reach the ears.

Q.23 A person has a hearing range from 20 Hz to 20 kHz. what are the typical wavelengths of sound waves in air corresponding to these two frequencies ? Take the speed of sound in air as 344 ms^{-1}.

Ans. Wavelength of sound of frequency 20 Hz

$$\lambda = \frac{\text{Speed of sound}}{\text{Frequency}} = \frac{344}{20} = 17.02\text{ m}$$

wavelength of sound of frequency 20,000 Hz

$$\lambda = \frac{\text{Speed of sound}}{\text{Frequency}} = \frac{344}{20{,}000} = 0.0172\text{ m}$$

Q.24 Two children are at opposite ends of an aluminium rod. One strikes the end of the rod with a stone. Find the ratio of times taken by the sound wave in air and in aluminium to reach the second child. Given velocity of sound in air and aluminium are 346 ms^{-1} and 6420 ms^{-1} respectively.

Ans. $$\frac{\text{Time taken by sound to travel in aluminium}}{\text{Time taken by sound air}} = \frac{\text{Speed of sound in air}}{\text{Speed of sound in aluminium}}$$

Time taken by sound in air Speed of sound in aluminium

$$\Rightarrow \quad \frac{T_{Alu.}}{T_{Air}} = \frac{346}{6420} \qquad \Rightarrow \quad T_{AIu} : T_{Air} = 346 : 6420 = 1 : 18.55$$

Q.25 The frequency of a source of sound is 100 Hz. How many times does it vibrate in a minute ?

Ans. No. of vibrations produced in 1 s = 100 $\Rightarrow$ No. of vibration produced in 60 (sec)

(1 min) = 100 × 60 = 6000

Q.26 Does sound follow the same laws of reflection as light does ? Explain.

Ans. Yes, sound and light follow the same laws of reflection given below :

(a) Angle of incidence at the point of incidence = Angle of reflection.

(b) At the point of incidence the incident sound wave, the normal and the reflected sound wave lie in the same plane.

Q.27 When a sound is reflected from a distant object, an echo is produced. Let the distance between the reflecting surface and the source of sound production remain the same. Do you hear echo sound on a hotter day ?

Ans. If the temperature rises the speed of sound will increase. This is turn will increase the minimum distance required for hearing an echo. No echo is heard because, the distance between the source of sound and reflecting body does not increase.

Q.28 Give two practical applications of reflection of sound waves.

Ans. (i) Megaphones are designed to send sound waves in particular direction are based on the reflection of sound.

(ii) In stethoscope the sound of patient's heartbeat reaches the doctor's ears by multiple reflection in the tubes.

Q.29 A stone is dropped from the top of a tower 500 m high into a pond of water at the base of the tower. When is the splash heard at the top ? Given, g = 10 ms^{-2} and speed of sound = 340 ms^{-1}.

Ans. For the downward journey of stone.

Initial velocity (u) = 0

Distance i.e., (height) of tower (S) = 500 m

Time of fall (t_1) = ?

Acceleration due to gravity (g) = 10 ms^{-2}

We know ; $S = ut + \frac{1}{2}gt^2$

$$500 = 0 \times t_1 + \frac{1}{2} \times 10 \times t_1^2$$

$\Rightarrow$ $500 = 5t_1^2$ $\Rightarrow$ $t_1^2 = 100$

$t_1 = 10$ s

For the sound travelling upward

Time taken (t_2)

For the sound travelling upward

$$\text{Time taken } (t_2) = \frac{\text{Total distance i.e., height}}{\text{Speed of sound}} = \frac{500}{340} = 1.47 \text{ s}$$

$\therefore$ Time required to hear splash = $t_1 + t_2$ = 10 + 1.47 = 11.47 s

Q.30 A sound wave travels at a speed of 339 ms^{-1}. If its wavelength is 1.5 cm, what is the frequency of the wave? Will it be audible ?

Ans. Speed of sound wave = 339 ms^{-1}

Wavelength of sound wave = 1.5 cm = 0.015 m

$\therefore$ Frequency of sound wave = $\frac{\text{Speed of sound}}{\text{Wavelength}} = \frac{339}{0.015} = 22600\,\text{Hz}$

The sound will not be audible, because human beings can hear only upto 20,000 Hz.

Q.31 What is reverberation? How can it be reduced ?

Ans. Reverberation is the repeated multiple reflections of sound in any big enclosed space. It can be reduced by covering the ceiling and walls of the enclosed space with some absorbing materials like fibre board, loose woollens etc.

Q.32 What is loudness of sound ? What factors does it depend on ?

Ans. Loudness of sound is the effect produced in the brain by the sound of different frequencies. The loudness of the sound depends on the distance of the observer from the source of sound ; lesser the distance louder the sound. It increases with the increase in amplitude and the area of the vibrating body.

Q.33 Explain how bats use ultrasound to catch their prey.

Ans. The bats produce high pitched ultrasonic waves which are not heard by human beings. The ultrasonic waves on striking the insect send back an echo, which is heard by the bat. As the echo is heard by the bat it hoves on the insect and catches it.

Q.34 How is ultrasound used for cleaning ?

Ans. The object to be cleaned is put in a tank fitted with ultrasonic vibrator. The tank is filled with water containing detergent. As the ultrasonic vibrator is switched on the detergent rub against the object at a very high speed and hence clean it.

Q.35 Explain the working and application of a sonar.

Ans. SONAR is a device for determining water depth and locating underwater objects like reefs, submarines and schools of fish.

On striking the bottom of the ocean, the ultrasonic wave is reflected upward toward the ship. This wave is received by a suitable receiver. The time of travel from the source of sound to the receiver is noted. We can calculate the depth of ocean floor if the velocity of sound in water is known

Depth of ocean floor = $\frac{\text{Velocity of sound in sea water} \times \text{time}}{2}$

For Example : If it takes 2.4 s to record echo by the sonar

Velocity of sound in sea water = 1450 ms^{-1}

Depth of ocean floor = $\frac{1450 \times 2.4}{2} = 1740\,\text{m}$

EXERCISE – I BOARD PROBLEMS

Q.1 A human heart, on an average, is found to beat 75 times in a minute. Calculate its frequency.

Q.2 Calculate the wavelength of a sound wave whose frequency is 220 Hz and speed is 440 m/s in a given medium

Q.3 A person is listening to a tone of 500 Hz sitting at a distance of 450 m from the source of the sound. What is the time interval between successive compressions from the source?

Q.4 A stone is dropped from the top of a tower 500 m high into a pond of water at the base of the tower. When is the splash heard at the top? Given, g = 10 ms^{-2} and speed of sound = 340 ms^{-1}.

Q.5 A sound wave travels at a speed of 339ms^{-1}. If its wavelength is 1.5 cm, what is the frequency of the wave? Will it be audible?

Q.6 A sonar device on a submarine sends out a signal and receives an echo 5 s later. Calculate the speed of sound in water if the distance of the object from the submarine is 3625 m.

Q.7 What is the frequency of a wave with a time period of 0.05 s?

Q.8 A bat can hear sound of frequency 100 kHz. Find the wavelength of the sound wave in air corresponding to this frequency. Given, speed of sound in air = 344 ms^{-1}.

Q.9 A boy heard a sound of frequency 100 Hz at a distance of 500 m from the source of sound. What is the time period of oscillating particles of the medium?

Q.10 The water waves are produced at a frequency of 40 Hz. If the wavelength of these waves is 2· 5 cm, calculate the speed of the waves.

Q.11 A radio station transmits waves of wavelength 200 m. If the speed of the waves is 3×10^8 m/s, find the frequency of the radio station.

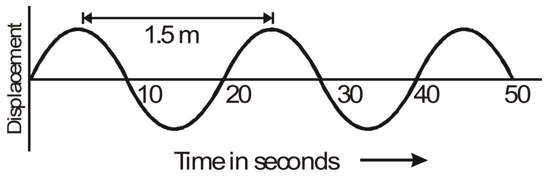
Q.12 Calculate the time taken by a sound wave of frequency 1000 Hz and wavelength 50 cm to travel a distance of 500 m.

Q.13 Audible range of frequencies is 20 Hz to 20,000 Hz. Find the range of wavelengths corresponding to this frequency. Given, velocity of sound = 340 ms^{-1}.

Q.14 A rock at the bank of a coast is struck by water waves. Find the frequency of the waves striking the rock, if the distance between two consecutive crests or troughs is 50 metre. Given, velocity of water wave = 50 ms^{-1}.

Q.15 A long spring whose one end is rigidly fixed is stretched from the other end and then left. Longitudinal waves of frequency 10 Hz are produced. If the velocity of the wave is 25 ms^{-1}, find the distance between two consecutive compressions in the spring.

Q.16 Find the velocity of the wave shown in the figure below.



Q.17 A man stands at a distance of 112 m from a vertical wall. On blowing a whistle, he hears the echo after 0.7 second. Calculate the speed of sound in air.

Q.18 A boy standing in front of a wall at 17 m produces 10 claps per second. He notice that the sound of his clapping coincides with the echo. Echo is heard only once when clapping is stopped. Calculate the speed of sound.

Q.19 A man stands at a distance of 25 m from a high wall. He hears the echo off the high wall, produced by a clap of his hands. If the velocity of sound is 330 ms^{-1}, what would be the time interval between his original clap and hearing of the echo ?

Q.20 A man fired a gun standing between two parallel cliffs. He heard two successive echoes after 3 and 5 seconds respectively. What is the distance between the cliffs. (Velocity of sound = 330 ms^{-1})

Q.21 A man makes a short and loud sound in front of a hill and the echo is heart after 3 seconds. On moving closer to the hill by 165 m, the echo is heard after 2 seconds. Calculate the velocity of sound and the distance of hill from the first position.

Q.22 A hospital uses an ultrasonic scanner to locate tumours in a tissue. What is the wavelength of sound in a tissue in which the speed of sound is 1.7 km s^{-1} ? The operating frequency of the scanner is 4.2 MHz.

Q.23 In a ripple tank, 10 full ripples/s are produced. The distance between a trough and a crest is 15 cm. Calculate:

(i) the frequency, (ii) the wavelength and

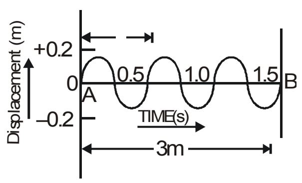
(iii) the velocity of the ripples

Q.24 Velocity of light in vacuum is 3×10^8 ms^{-1} and that in water 2.3×10^8 ms^{-1}. If the wavelength of a wave in vacuum is 6×10^{-7} m, what will be its wavelength in water ? What is the frequency of the wave ?

Q.25 A source of sound produces waves of wavelength 0.80 m in air. The same source of sound produces waves of wavelength 4.0 m in water. If the velocity of sound in air = 332 ms^{-1}, find the velocity of sound in water.

Q.26 The wave form represent's a transverse wave produced on a taut string AB which is vibrated at A.

(i) What is the amplitude of the waves ?



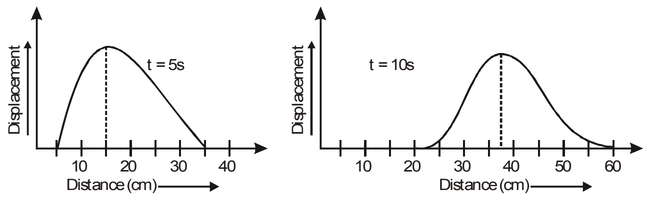
(ii) Mark the wavelength λ on the diagram. State its value.

(iii) Calculate the time period of the vibration.

(iv) Calculate the frequency of the source.

(v) Calculate the velocity of the transverse wave.

Q.27 The following graph shows the displacement vs distance of a pulse on a rope at two different times. Find the speed of the pulse.



Q.28 Two sound wave in air have wavelength ratio 1 : 3. Find their frequency ratio.

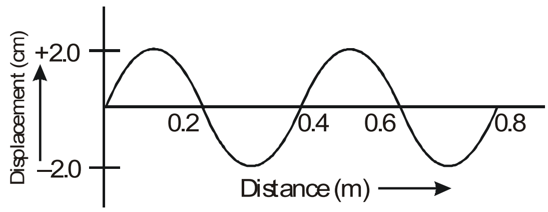
Q.29 A source produces 15 crests and 15 through in 3 seconds. When the second crest is produced, the first is 2 cm away from the source. Calculate

(i) the wavelength

(ii) the frequency, and

(iii) the wave speed.

Q.30 Shown in figure a displacement-distance time graph for a wave. The wave velocity is 320 ms^{-1}. Determine



(i) wavelength (ii) frequency, and

(iii) amplitude

MARK THE STATEMENTS TRUE OR FALSE

Q.1 Sound waves are transverse whereas light waves are longitudinal in nature.

Q.2 Distance between a crest and the next trough in a wave motion is $\lambda/4$.

Q.3 The audible range of frequencies is 20Hz - 20 kHz.

Q.4 The frequency of a sounding body of time period 0.01 sec is 100 Hz.

Q.5 The minimum distance between a source and the reflector of sound should be 34 m.

Q.6 Sound waves travel faster in air than in water.

Q.7 Sound travels faster at a higher temperature than at a lower temperature.

Q.8 Sound and light travel in a medium in the form of crests and troughs and rarefactions and compressions respectively.

Q.9 Light waves require no medium for their propagation.

Q.10 Sound produced by a sounding body of frequency 300 Hz covers 34 m in the time the sounding body produces 30 vibrations.

Q.11 Velocity of sound in air is more for higher frequency than for lower frequency.

Q.12 The wavelength of 5 MHz ultrasound in a medium where the velocity is 1540 ms^{-1} is 0.3 mm.

FILL IN THE BLANKS

Q.1 A wave is a ____________ in a medium.

Q.2 Waves transport ____________ and not ____________ from one region to the other.

Q.3 If the particles of the medium vibrate ____________ to the direction of propagation of the wave then the wave is called a transverse wave.

Q.4 Transverse waves can't be transmitted inside ____________

Q.5 If the particles of the medium vibrate ____________ to the direction of the propagation of the wave then the wave is called longitudinal wave.

Q.6 The speed of sound in a medium depends upon ____________ of the medium and ____________ of the medium.

Q.7 Sound travels more than ____________ times faster in water and more than ____________ times faster in steel than it does in air.

Q.8 Ultrasonic are the frequencies which are ____________ than 20,000 Hz.

Q.9 Infrasonic are the frequencies which are lesser than ____________.

Q.10 The audible range for a normal human is ____________ to 20,000 Hz

Q.11 An echo is the phenomenon of ____________ of sound of a source by reflection from an obstacle.

Q.12 The sensation of sound lasts on our ears for ____________ of a second. This is called persistence of hearing.

Q.13 The minimum distance between a source and the reflector of sound to hear an echo is ____________.

Q.14 SONAR is a technique of determining locating objects ____________.

MATCH THE COLUMN

Q.1

	COLUMN–I		COLUMN–II
(A)	Sound waves.	(p)	electromagnetic wave.
(B)	Waves in strings.	(q)	longitudinal wave.
(C)	Waves in a slinky.	(r)	transverse wave.
(D)	Light waves.	(s)	both transverse and longitudinal.

Q.2

	COLUMN–I		COLUMN–II
(A)	Crest.	(p)	longitudinal wave.
(B)	Compression.	(q)	v/λ
(C)	Frequency.	(r)	transverse wave.
(D)	Wavelength.	(s)	distance between two consecutive rarefactions.

Each question, in this section, contains statements given in two columns which have to be matched. The statements in Column I are labelled A, B, C and D, while the statements in Column II are labelled p, q, r, s and t. Any given statement in Column I can have correct matching with ONE OR MORE statement(s) in Column II.

Q.3

	COLUMN–I		COLUMN–II
(A)	Degree of sensation of sound.	(p)	loudness.
(B)	Amplitude.	(q)	quality.
(C)	Frequency.	(r)	intensity.
(D)	Timbre.	(s)	shrillness.
		(t)	pure note.

Q.4

	COLUMN–I		COLUMN–II
(A)	Multiple reflection of sound.	(p)	galton whistle.
(B)	Infrasonics.	(q)	ear.
(C)	Pinna.	(r)	stethoscope.
(D)	Anvil.	(s)	sound boards.
		(t)	lesser than 20 Hz.

ANSWER KEY

1. $1.25\ s^{-1}$ **4.** 11.47 sec

5. 22600 Hz, not be audible

6. 1450 m/s **7.** 20 Hz

8. 3.44 mm **9.** time period = 0.01 sec

10. 1 m/s **11.** 1.5×10^6 Hz

12. t = 1 sec, v = 500 m/s

13. λ = 17m, 0.017 m

14. 1 Hz **15.** 2.5 m

16. $0.075\ ms^{-1}$ **17.** $320\ ms^{-1}$

18. $340\ ms^{-1}$ **19.** 0.15 s

20. 1320 m

21. $330\ ms^{-1}$, 450 m **22.** $4.0\times\ 10^{-4}$ m

23. (i) 10 Hz, (ii) 30 cm, (iii) $3\ ms^{-1}$

24. 4.6×10^{-7} m **25.** $1660\ ms^{-1}$

26. (i) 0.2 m, (ii) 1 m, (iii) 0.5 s, (iv) 2 Hz, (v) $2\ ms^{-1}$

27. $4.5\ cm\ s^{-1}$ **28.** 3 : 1

29. (i) 2 cm ; (ii) 5 Hz ; (iii) $10\ cm\ s^{-1}$

30. (i) 0.4 m ; (ii) 800 Hz ; (iii) 2 cm

TRUE AND FALSE

1. False **2.** False **3.** True

4. True **5.** False **6.** False

7. True **8.** False **9.** True

10. True **11.** False **12.** True

FILL IN THE BLANKS

1. disturbance **2.** energy, matter

3. perpendicular **4.** liquids and gases

5. parallel **6.** nature, density

7. four, seven **8.** greater

9. 20 Hz **10.** 20 Hz

11. repetition **12.** one-tenth

13. 17 metre **14.** under water

MATCH THE COLUMN

1. (A $\rightarrow$ q), (B $\rightarrow$ r), (C $\rightarrow$ s), (D $\rightarrow$ p)

2. (A $\rightarrow$ r), (B $\rightarrow$ p), (C $\rightarrow$ q), (D $\rightarrow$ s)

3. (A $\rightarrow$ p), (B $\rightarrow$ p, r), (C $\rightarrow$ s, t), (D $\rightarrow$ q)

4. (A $\rightarrow$ r, s), (B $\rightarrow$ t), (C $\rightarrow$ q), (D $\rightarrow$ q)

EXERCISE – II | OLYMPIAD QUESTIONS

Q.1 A part of longitudinal wave in which particles of medium are farther away than the normal particles is called:

(A) rarefaction (B) trough

(C) compression (D) crest

Q.2 In case of a longitudinal wave, in the region of rarefaction :

(A) the volume of momentarily increases

(B) the density momentarily decreases

(C) the pressure momentarily decreases

(D) all the above

Q.3 In the region of compression or rarefaction, in a longitudinal wave the physical quantity which does not change is:

(A) pressure (B) mass

(C) density (D) volume

Q.4 A slinky can produce in laboratory :

(A) transverse waves only

(B) longitudinal waves only

(C) both (A) and (B)

(D) none of the above

Q.5 In case of transverse wave :

(A) the hump on the + y axis is called crest

(B) the hump on the – y axis is called crest

(C) the highest point on the hump on + y axis is called crest

(D) the highest point on the hump on the – y axis is called crest

Q.6 In case of transverse wave:

(A) the hump on the – y axis is called trough

(B) the lowest point the hump on the – y axis is called trough

(C) the hump on + y axis is called trough

(D) the highest point on the hump on the + y axis is called trough

Q.7 The wavelength is the linear distance between the:

(A) two consecutive compressions

(B) two consecutive rarefactions

(C) one compression and one rarefaction

(D) both (A) and (B)

Q.8 In case of transverse wave the wavelength is the linear distance between :

(A) two consecutive troughs

(B) two consecutive crests

(C) one crest and one trough

(D) both (A) and (B)

Q.9 The change in density/pressure of a medium from maximum value to minimum value and again to maximum value, due to the propagation of a longitudinal wave is called complete:

(A) oscillation (B) frequency

(C) amplitude (D) none of the above

Q.10 The number of oscillations passing through a point in unit time is called:

(A) vibration (B) frequency

(C) wavelength (D) none of the above

Q.11 The SI unit of frequency is :

(A) hertz (B) gauss

(C) decibel (D) none of the above

Q.12 If the frequency of a wave is 25 Hz, the total number of compressions and rarefactions passing through a point in 1 second is

(A) 25 (B) 50

(C) 100 (D) none of the above

Q.13 Time period of a wave in a medium is the time taken by:

(A) a compression to pass through a point

(B) a rarefaction to pass through a point

(C) an oscillation to pass through a point

(D) none of the above

Q.14 Amplitude of a longitudinal wave in a medium:

(A) is the extent to which a medium gets compressed

(B) is the extent to which a medium gets rarefied

(C) either (A) or (B)

(D) none of the above

Q.15 Non-mechanical (electromagnetic) wave can propagate in :

(A) material medium as well as vacuum

(B) in vacuum, but not in material medium

(C) in material medium but not in vacuum

(D) neither in material medium nor in vacuum

Q.16 The linear distance between a compression and a rarefaction or a crest and a trough is :

(A) $\frac{\lambda}{2}$ (B) $\frac{\lambda}{4}$

(C) λ (D) $\frac{3\lambda}{2}$

Q.17 A longitudinal wave travels in water from west to east. The direction which the particles of medium move:

(A) east to west (B) west to east
(C) north to south (D) south to north

Q.18 A stretched string is plucked gently to produce a note. The string is producing:

(A) longitudinal waves

(B) stationary waves

(C) transverse waves

(D) both (A) and (C)

Q.19 A stretched slinky is given a sharp push along its length. A wave travels from one end to another. The wave so produced is :

(A) transverse wave (B) longitudinal wave
(C) stationary wave (D) none of the above

Q.20 A longitudinal sound wave in air consists:

(A) a number of rarefaction pulses one after the other

(B) a number of compression pulses one after the other

(C) compression and rarefaction pulses alternating with each other

(D) a rarefaction pulse followed by compression pulse, separated by some distance.

Q.21 The density of air at some point in a longitudinal sound wave is minimum at an instant. The pressure of air at that point is :

(A) minimum

(B) maximum

(C) equal to atmospheric pressure

(D) none of the above

Q.22 Which of the following is an elastic wave?

(A) light wave (B) radio waves
(C) sound wave (D) microwaves

Q.23 Infrasonic vibrations have frequency:

(A) less than 10Hz

(B) less than 20 Hz

(C) between 20 and 20,000 Hz

(D) more than 20,000 Hz.

Q.24 The range of sonic waves is between:

(A) 20 Hz to 2000 Hz

(B) 20 Hz to 10,000 Hz

(C) 20 Hz to 15,000 Hz

(D) 20 Hz to 20,000 Hz

Q.25 The sound waves having a frequency more than 20,000 Hz are called:

(A) infrasonic waves (B) supersonic waves

(C) ultrasonic waves (D) hypersonic waves

Q.26 The animal which cannot hear ultrasonic waves is :

(A) bat (B) cow

(C) dog (D) dolphin

Q.27 The bat hunts it prey by emitting and receiving reflected:

(A) super sonic waves

(B) ultrasonic waves

(C) sonic waves

(D) infrasonic waves

Q.28 A sonic boom is produced in the air when an aircraft flies at a speed:

(A) equal to the speed of sound

(B) more than the speed of sound

(C) less than the speed of sound

(D) climbs vertically

Q.29 Sound travels fastest in :

(A) vacuum (B) gases

(C) solids (D) liquids

Q.30 A boy sitting in a boat fires a gun. An observer P is at a distance of 50 m from the boat. Another observer Q is a diver, who is 50 m under water. Both hear the sound of gun:

(A) P hears the sound first

(B) Q hears the sound first

(C) Both P and Q hear the sound at the same time

(D) none of the above.

Q.31 When the lightning strikes, we hear multiple of cracks of thunder. These multiple reflections of sound are called:

(A) echoes (B) reverberations
(C) resonance (D) none of the above.

Q.32 Hearing of repetition of sound after reflection from a distant object is called:

(A) reverberation (B) resonance

(C) echo (D) none of the above.

Q.33 For hearing an echo the minimum distance should be :

(A) less than 10m

(B) between 10m and 15 m

(C) 17 m or more

(D) none of the above.

Q.34 An echo is heard only, if the original sound after reflection should reach the ear in :

(A) less than $\frac{1}{100}$ s (B) less than $\frac{1}{10}$ s

(C) more than $\frac{1}{10}$ s (D) none of the above.

Q.35 A bullet is moving at a speed, more than the speed of sound. It is said to be moving at :

(A) supersonic speed

(B) ultrasonic speed

(C) infrasonic speed

(D) sonic speed

Q.36 Naval ships called "destroyers" can detect submarines in the sea. The device used by these ships is called:

(A) ultra sonometer (B) sonar

(C) ultrasonograph (D) none of the above .

Q.37 Which of the following properties of a sound wave are affected by the change in temperature of air:

(A) frequency (B) amplitude

(C) wavelength (D) intensity

Q.38 Which of the following gases the sound travels fastest:

(A) hydrogen (B) helium

(C) nitrogen (D) oxygen

Q.39 The waves used in sonography as :

(A) microwaves

(B) ultra-violet waves

(C) ultrasonic waves

(D) sound waves

Q.40 The crack of thunder is heard after few seconds the lightning flash, because:

(A) crack of thunder and lightning are not produced at same time

(B) light travels extremely fast as compared to sound

(C) sound waves slow down on passing through air

(D) none of the above

Q.41 Sound energy is basically:

(A) mechanical energy

(B) electromagnetic energy

(C) potential energy

(D) electrical energy

Q.42 The transfer of energy in a material medium due to the periodic motion of its particles is called:

(A) wave front (B) wave motion

(C) pulse (D) none of the above

Q.43 Which is not the condition for hearing sound?

(A) There must be a vibrating body capable of transferring energy.

(B) There must be a material medium to pick up and propagate energy

(C) The medium must have a large density.

(D) There must be receiver to receive the energy and interpret it.

Q.44 An instrument commonly used in laboratory to produce a sound of some particular frequency is:

(A) sonar (B) electric bell

(C) tuning fork (D) a stretched wire

Q.45 The sound waves in a medium are characterised by the:

(A) linear motion of particles in the medium

(B) rotatory motion of particles in the medium

(C) oscillatory motion of particles in the medium

(D) none of the above

Q.46 The sound waves which travel in the air are called:

(A) transverse waves

(B) longitudinal waves

(C) polarised waves

(D) none of the above

Q.47 When a sound wave travels in the air, the physical quantity which is transferred from one place to the other is:

(A) mass (B) force

(C) momentum (D) energy

Q.48 In case of longitudinal waves, the particles of medium vibrate:

(A) in the direction of wave propagation

(B) opposite to the direction of wave propagation

(C) at right angles to the direction of wave propagation

(D) none of the above

Q.49 In case of transverse waves the particles of a medium vibrate:

(A) in the direction of wave propagation

(B) opposite to the direction of wave propagation

(C) at the right angles to the direction of wave propagation

(D) none of the above

Q.50 A longitudinal waves consists of:

(A) crest and troughs in the medium

(B) compressions and rarefactions in the medium

(C) both (A) and (B)

(D) neither (A), nor (B)

Q.51 A transverse wave consists of:

(A) crests and troughs in the medium

(B) compressions and rarefactions in the medium

(C) both (A) and (B)

(D) neither (A), nor (B)

Q.52 The longitudinal waves can propagate only in :

(A) solids (B) liquids

(C) gases (D) all the above

Q.53 The transverse waves can propagate only in :

(A) liquids (B) gases

(C) solids (D) vacuum

Q.54 A part of the longitudinal wave in which particles of medium are closer than the normal particles is called:

(A) rarefaction (B) crest

(C) trough (D) compression

Q.55 In the compression region of the medium in case of longitudinal wave:

(A) the volume monetarily decreases

(B) the density momentarily increases

(C) the pressure monetarily increases

(D) all the above

Q.56 In which of the following media will sound travel the fastest? **[NTSE]**

(A) solid (B) both solid and liquid

(C) liquid (D) gas

Q.57 Sound waves in air are _______ waves. **[NTSE]**

(A) longitudinal (B) radio

(C) transverse (D) electromagnetic

Q.58 Sound waves cannot pass through: **[NTSE]**

(A) a solid-liquid mixture

(B) an ideal gas

(C) a liquid-gas mixture

(D) a perfect vacuum

Q.59 Out of the following, which frequency is not clearly audible to the human ear? **[NTSE]**

(A) 30 Hz (B) 30,000 Hz

(C) 300 Hz (D) 3000 Hz

Q.60 The frequency of sound waves can be expressed in: **[NTSE]**

(A) Hz only (B) cycles/second only

(C) s^{-1} only (D) all the above

Q.61 Sound waves are: **[NTSE]**

(A) transverse mechanical waves

(B) longitudinal mechanical waves

(C) neither (A) nor (B)

(D) none of these

Q.62 The speed of sound wave in a given medium is: **[NTSE]**

(A) directly proportional to its frequency

(B) inversely proportional to its frequency

(C) directly proportional to the square of its frequency

(D) independent of its frequency

Q.63 *Supersonic* means: **[NTSE]**

(A) frequencies less than 20 Hz

(B) same as ultrasonic

(C) frequencies much more than that of ultrasonics

(D) same as infrasonics

Q.64 The frequency of a wave is 5 Hz. It refers to (types of wave) **[NTSE]**

(A) ultrasonics (B) microwaves
(C) infrasonics (D) radio waves

Q.65 When a vibrating tuning fork is placed on a table, a large sound is heard. This is due to: **[NTSE]**

(A) forced vibrations (B) resonance
(C) beats (D) reflection

Q.66 A body produces sound only if it is: **[NTSE]**

(A) made of steel (B) made of glass
(C) plucked (D) vibrating

Q.67 Velocity of sound is minimum in: **[NTSE]**

(A) nitrogen (B) hydrogen
(C) air (D) carbon dioxide

Q.68 Sound takes some time to travel from one place to another. It will be maximum: **[NTSE]**

(A) at night (B) during summer
(C) during winter (D) all the time same

Q.69 The sound propagates in a gaseous medium by: **[NTSE]**

(A) transverse waves
(B) longitudinal waves
(C) both (A) and (B)
(D) neither (A) and (B)

Q.70 Echo is produced due to: **[NTSE]**

(A) reflection of sound
(B) refraction of sound
(C) resonance
(D) none of these

Q.71 SONAR is based on the principle of: **[NTSE]**

(A) echo (B) resonance
(C) reverberation (D) any one of the above

Q.72 The audible range of frequency is: **[NTSE]**

(A) 20 Hz to 20,000 Hz
(B) 40 Hz to 40,000 Hz
(C) 60 Hz to 60,000 Hz
(D) 10 Hz to 20,000 Hz

Q.73 Which of the following frequencies of sound cannot be heard by human beings? **[NTSE]**

(A) 5Hz (B) 20 Hz
(C) 400 Hz (D) 1000 Hz

Q.74 Velocity of sound in air is about: **[NTSE]**

(A) 330 m/s (B) 360 m/s
(C) 380 m/s (D) 400 m/s

Q.75 A echo will be heard if the minimum distance between the source of sound and the obstacle is: **[NTSE]**

(A) 1 m (B) 10 m
(C) 15 m (D) 17 m

ANSWER KEY

1.	A	**2.**	D	**3.**	B	**4.**	C
5.	C	**6.**	B	**7.**	D	**8.**	D
9.	A	**10.**	B	**11.**	A	**12.**	B
13.	C	**14.**	C	**15.**	A	**16.**	A
17.	B	**18.**	C	**19.**	B	**20.**	C
21.	A	**22.**	C	**23.**	B	**24.**	D
25.	C	**26.**	B	**27.**	B	**28.**	B
29.	C	**30.**	B	**31.**	B	**32.**	C
33.	C	**34.**	C	**35.**	A	**36.**	B
37.	C	**38.**	A	**39.**	C	**40.**	B
41.	A	**42.**	B	**43.**	C	**44.**	C
45.	C	**46.**	B	**47.**	D	**48.**	A
49.	C	**50.**	B	**51.**	A	**52.**	D
53.	C	**54.**	D	**55.**	D	**56.**	B
57.	B	**58.**	C	**59.**	D	**60.**	A
61.	B	**62.**	A	**63.**	B	**64.**	C
65.	A	**66.**	D	**67.**	D	**68.**	C
69.	B	**70.**	A	**71.**	A	**72.**	A
73.	A	**74.**	A	**75.**	D		

EXERCISE – III NTSE QUESTIONS

1. A part of longitudinal wave in which particles of medium are farther away than the normal particles is called:

(A) rarefaction (B) trough (C) compresion (D) crest

2. In case of a longitudinal wave, in the region of rarefaction :

(A) the volume of momentarily increases (B) the density momentarily decreases

(C) the pressure momentarily decreases (D) all the above

3. In the region of compression or rarefaction, in a longitudinal wave the physical quantity which does not change is:

(A) pressure (B) mass (C) density (D) volume

4. A slinky can produce in laboratory :

(A) transverse waves only (B) longitudinal waves only

(C) both (A) and (B) (D) none of the above

5. In case of transverse wave :

(A) the hump on the + y axis is called crest

(B) the hump on the – y axis is called crest

(C) the highest point on the hump on + y axis is called crest

(D) the highest point on the hump on the – y axis is called crest

6. In case of transverse wave:

(A) the hump on the – y axis is called trough

(B) the lowest point the hump on the – y axis is called trough

(C) the hump on + y axis is called trough

(D) the highest point on the hump on the + y axis is called trough

7. The wavelength is the linear distance between the:

(A) two consecutive compressions

(B) two consecutive rarefactions

(C) one compression and one rarefaction

(D) both (A) and (B)

8. In case of transverse wave the wavelength is the linear distance between :

(A) two consecutive troughs (B) two consecutive crests

(C) one crest and one trough (D) both (A) and (B)

9. The change in density/pressure of a medium from maximum value to minimum value and again to

maximum value, due to the propagation of a longitudinal wave is called complete:

(A) oscillation (B) frequency (C) amplitude (D) none of the above

10. The number of oscillations passing through a point in unit time is called:

(A) vibration (B) frequency (C) wavelength (D) none of the above

11. The SI unit of frequency is :

(A) hertz (B) gauss (C) decibel (D) none of the above

12. If the frequency of a wave is 25 Hz, the total number of compressions and rarefactions passing through a point in 1 second is

(A) 25 (B) 50 (C) 100 (D) none of the above

13. Time period of a wave in a medium is the time taken by:

(A) a compression to pass through a point (B) a rarefaction to pass through a point

(C) an oscillation to pass through a point (D) none of the above

14. Amplitude of a longitudinal wave in a medium:

(A) is the extent to which a medium gets compressed

(B) is the extent to which a medium gets rarefied

(C) either (A) or (B) (D) none of the above

15. Non-mechanical (electromagnetic) wave can propagate in :

(A) material medium as well as vacuum (B) in vacuum, but not in material medium

(C) in material medium but not in vacuum (D) neither in material medium nor in vacuum

16. The linear distance between a compression and a rarefaction or a crest and a trough is :

(A) $\frac{\lambda}{2}$ (B) $\frac{\lambda}{4}$ (C) λ (D) $\frac{3\lambda}{2}$

17. A longitudinal wave travels in water from west to east. The direction which the particles of medium move:

(A) east to west (B) west to east (C) north to south (D) south to north

18. A stretched string is plucked gently to produce a note. The string is producing:

(A) longitudinal waves (B) stationary waves (C) transverse waves (D) both (A) and (C)

19. A stretched slinky is given a sharp push along its length. A wave travels from one end to another. The wave so produced is :

(A) transverse wave (B) longitudinal wave (C) stationary wave (D) none of the above

20. A longitudinal sound wave in air consists:

(A) a number of rarefaction pulses one after the other

(B) a number of compression pulses one after the other

(C) compression and rarefaction pulses alternating with each other

(D) a rarefaction pulse followed by compression pulse, separated by some distance.

21. The density of air at some point in a longitudinal sound wave is minimum at an instant. The pressure of air at that point is :

(A) minimum
(B) maximum
(C) equal to atmospheric pressure
(D) none of the above

22. Which of the following is an elastic wave?

(A) light wave (B) radio waves (C) sound wave (D) microwaves

23. Infrasonic vibrations have frequency:

(A) less than 10Hz
(B) less than 20 Hz
(C) between 20 and 20,000 Hz
(D) more than 20,000 Hz.

24. The range of sonic waves is between:

(A) 20 Hz to 2000 Hz
(B) 20 Hz to 10,000 Hz
(C) 20 Hz to 15,000 Hz
(D) 20 Hz to 20,000 Hz

25. The sound waves having a frequency more than 20,000 Hz are called:

(A) infrasonic waves
(B) supersonic waves
(C) ultrasonic waves
(D) hypersonic waves

26. The animal which cannot hear ultrasonic waves is :

(A) bat (B) cow (C) dog (D) dolphin

27. The bat hunts it prey by emitting and receiving reflected:

(A) super sonic waves (B) ultrasonic waves (C) sonic waves (D) infrasonic waves

28. A sonic boom is produced in the air when an aircraft flies at a speed:

(A) equal to the speed of sound
(B) more than the speed of sound
(C) less than the speed of sound
(D) climbs vertically

29. Sound travels fastest in :

(A) vacuum (B) gases (C) solids (D) liquids

30. A boy sitting in a boat fires a gun. An observer P is at a distance of 50 m from the boat. Another observer Q is a diver, who is 50 m under water. Both hear the sound of gun:

(A) P hears the sound first (B) Q hears the sound first

(C) Both P and Q hear the sound at the same time (D) none of the above.

31. When the lightning strikes, we hear multiple of cracks of thunder. These multiple reflections of sound are called:

(A) echoes (B) reverberations (C) resonance (D) none of the above.

32. Hearing of repetition of sound after reflection from a distant object is called:

(A) reverberation (B) resonance (C) echo (D) none of the above.

33. For hearing an echo the minimum distance should be :

(A) less than 10m (B) between 10m and 15 m

(C) 17 m or more (D) none of the above.

34. An echo is heard only, if the original sound after reflection should reach the ear in :

(A) less than $\frac{1}{100}$ s (B) less than $\frac{1}{10}$ s (C) more than $\frac{1}{10}$ s (D) none of the above.

35. A bullet is moving at a speed, more than the speed of sound. It is said to be moving at :

(A) supersonic speed (B) ultrasonic speed (C) infrasonic speed (D) sonic speed

36. Naval ships called "destroyers" can detect submarines in the sea. The device used by these ships is called:

(A) ultra sonometer (B) sonar (C) ultrasonograph (D) none of the above .

37. Which of the following properties of a sound wave are affected by the change in temperature of air:

(A) frequency (B) amplitude (C) wavelength (D) intensity

38. Which of the following cases the sound travels fastest:

(A) hydrogen (B) helium (C) nitrogen (D) oxygen

39. The waves used in sonography as :

(A) microwaves (B) ultra-violet waves (C) ultrasonic waves (D) sound waves

40. The crack of thunder is heard after few seconds the lightning flash, because:

(A) crack of thunder and lightning are not produced at same time

(B) light travels extremely fast as compared to sound

(C) sound waves slow down on passing through air

(D) none of the above

SOUND

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ans.	A	D	B	C	C	B	D	D	A	B	A	B	C	C	A
Que.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Ans.	A	B	C	B	C	A	C	B	D	C	B	B	B	C	B
Que.	31	32	33	34	35	36	37	38	39	40					
Ans.	B	C	C	C	A	B	C	A	C	B					